Appendix F

Planning-Level Sizing Assumptions

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Appendix F.1

Storage Tank Design Criteria

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Facility Component	Design Criteria	Footprint Criteria
Storage Tank	a) Discharge into storage tank via gravity and pump to drain. b) Maximum Water Surface Level = Existing Overflow Elevation (When Feasible); Freeboard Depth = 2 feet. a. Existing overflow elevation is the water level at which combined sewage is diverted to the existing CSO outfall, either via an overflow weir or outfall gate. b. Two feet of freeboard is assumed to allow the system to balance and discharge to the CSO outfall when the storage tank is full. c. If site-specific conditions require the storage tank to be constructed deeper, then it may be possible that the maximum water surface level is lower than the existing overflow elevation. In these instances, the maximum water surface level would be assumed to be 1 foot below the invert of the inlet conveyance piping into the storage tank, and isolation valves could be used to prevent surcharging of the storage tank. c) Flushing Lane: 2% slope. d) Tank Cover Depth: minimum 2 feet. e) Water Depth in Tank: 10 to 20 feet. f) Tipping buckets will be used for flushing.	a) Tank Length to Width Ratio: 3:1 or 5:1. b) Outer Wall Thickness: 3 feet. c) Dividing Wall Thickness: 1 foot. d) Additional Length and Width for Shoring: 5 feet each side.

Facility Component	Design Criteria	Footprint Criteria
Electrical/Controls/Standby Generator Building	**<u>Power Requirements:</u>** -Flushing mechanism -Sluice gate(s) at end of chamber -Control gate(s) in diversion structure -Drain pumps -Odor control fan -Power panels (lighting, receptacles, etc.) -All equipment, including odor control fan, is on the standby generator.	a) Electrical/Controls/Standby Generator Building Area = 20% of storage tank footprint.
Odor Control Facility	Carbon bed vessel, exhaust fan with acoustical enclosure, mist eliminator, silencer, ductwork with bypass for connection to MOCU. The ventilation rate would be two air exchanges per hour (ac/hr) to control odors, with provisions including a variable speed drive for the odor control fan and bypass ductwork for 6 ac/hr to bypass the carbon scrubber and facilitate manned entry into storage facility.	a) Preliminary sizing of odor control unit vessel footprint based on 2 air exchanges per hour for an empty storage tank with additional footprint included for ancillary equipment. Fire Marshall review may result in greater ventilation rate requirement than 2 air exchanges per hour.
Conveyance Piping to Storage Tank	a) Discharge into storage tank via gravity if feasible (free discharge). b) Conveyance piping sized for maximum overflow rate of events that are at or less than 1-year recurrence by volume based on King County 32-year model simulations. c) Use Manning Equation for pipe sizing (Manning coefficient, n = 0.013). d) For open cut construction, excavation depth is less than 25 feet deep. If excavation is greater than 25 feet deep, then microtunneling construction methods are assumed.	

Facility Component	Design Criteria	Footprint Criteria
Force Main (Draining Storage Tank) and Drain Pumping System	a) Single force main. b) Design to accommodate storage facility drawdown in 12 hours. c) Maintain a velocity between 4 and 10 feet per second.	a) Submersible pumps are located within storage tank footprint area.
Diversion Structure	a) Locate diversion structure as required to convey combined sewage to storage tank. General assumption is that diversion would occur at existing regulator stations. b) Diversion structure consists of overflow weirs and gates. Details of operation will be determined during Predesign. c) Elevation of new overflow weir that diverts combined sewage to storage tank is below the existing overflow elevation (water level at which combined sewage is diverted to the existing CSO outfall, either via an overflow weir or outfall gate).	Assume standard 15’ x 15’ footprint.
C2 Water Service	**C2 Water System for Tipping Buckets:** Break tank Fill pumps Backflow preventer	Assume standard 10’ x 10’ footprint.

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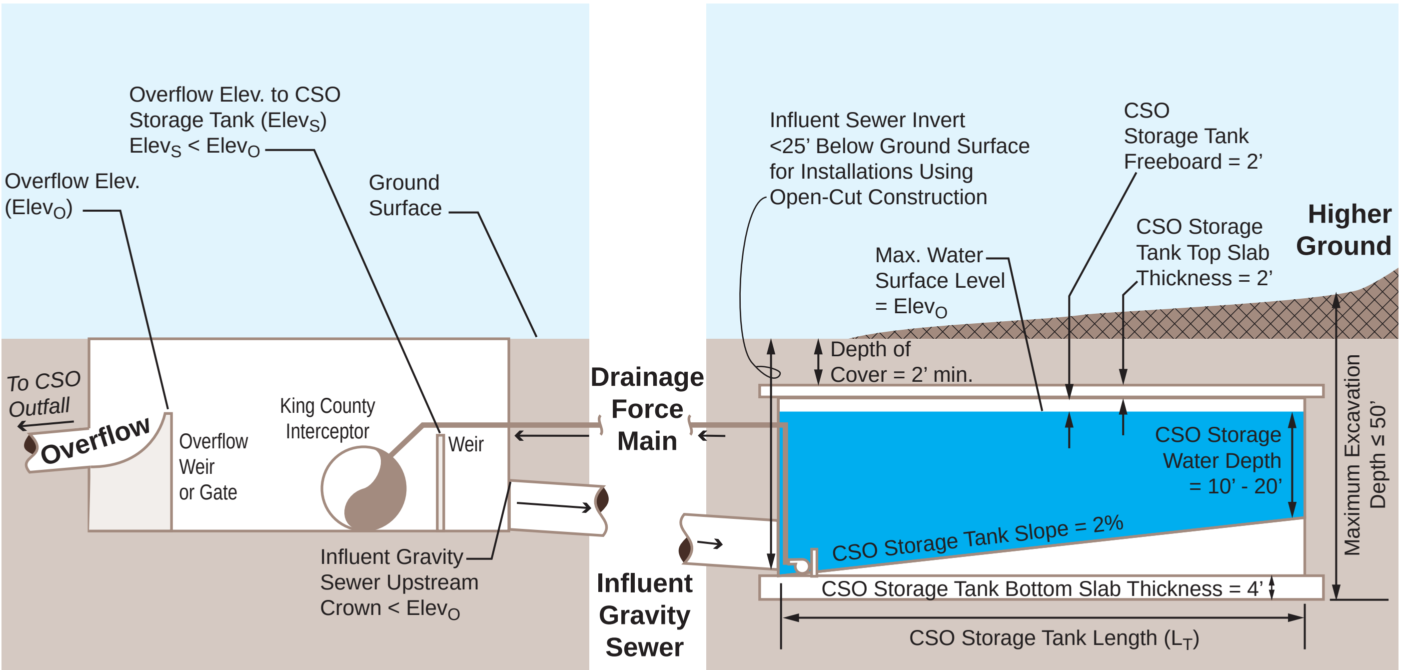
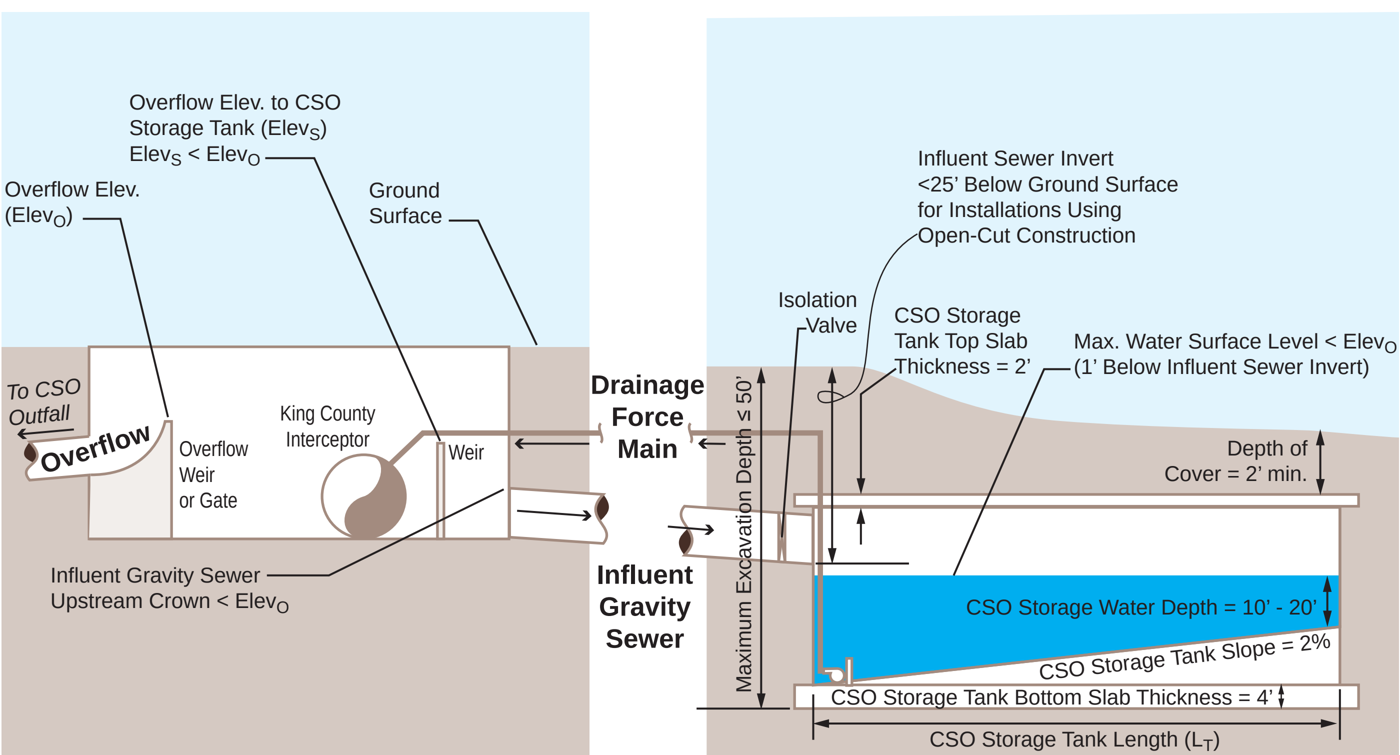
CSO Storage Tank Design Criteria
(Maximum Water Surface Level = Overflow Elevation)



Diversion Location (Regulator Station)

CSO Storage Tank

CSO Storage Tank Design Criteria
(Maximum Water Surface Level < Overflow Elevation)



Diversion Location (Regulator Station)

CSO Storage Tank

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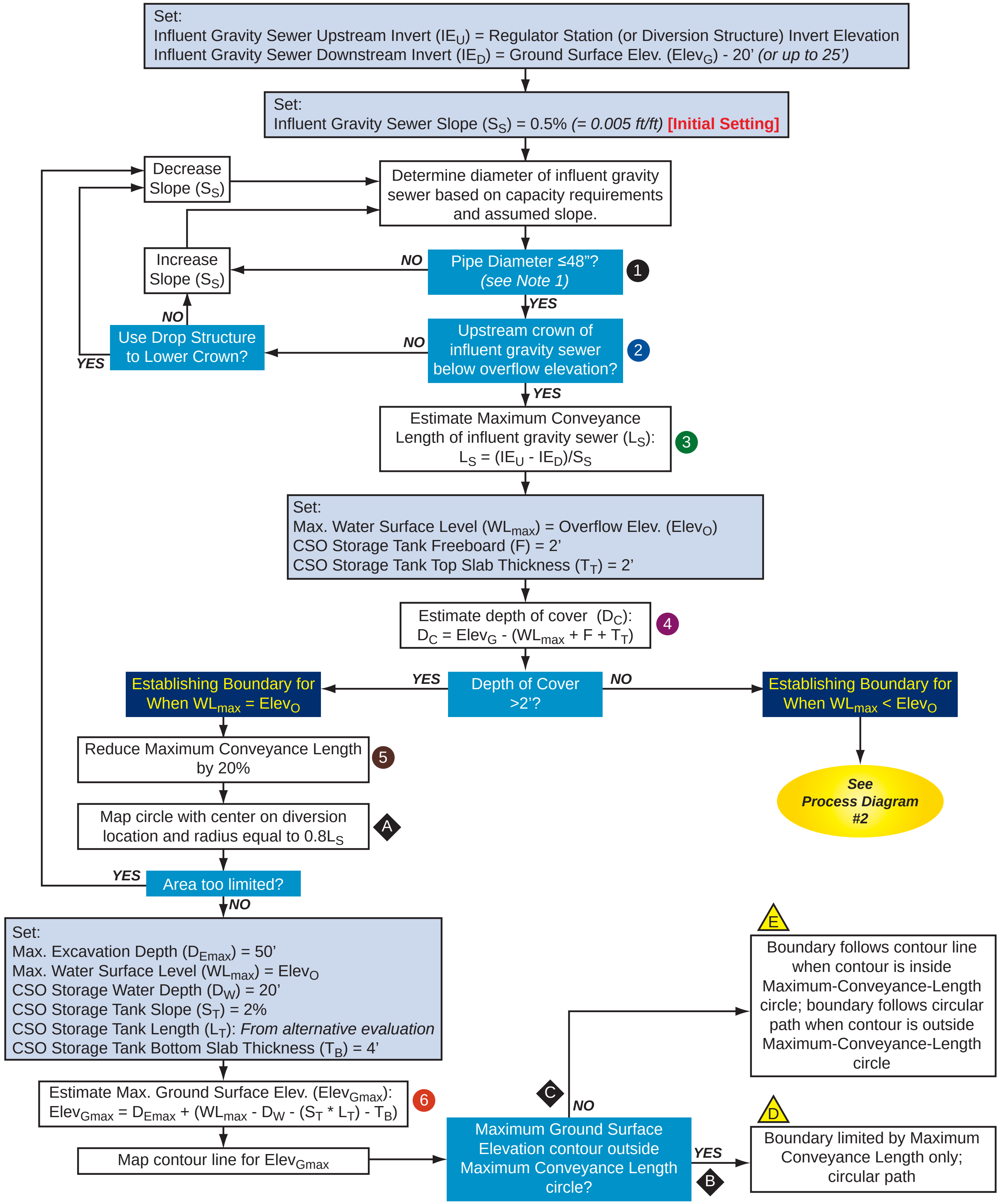
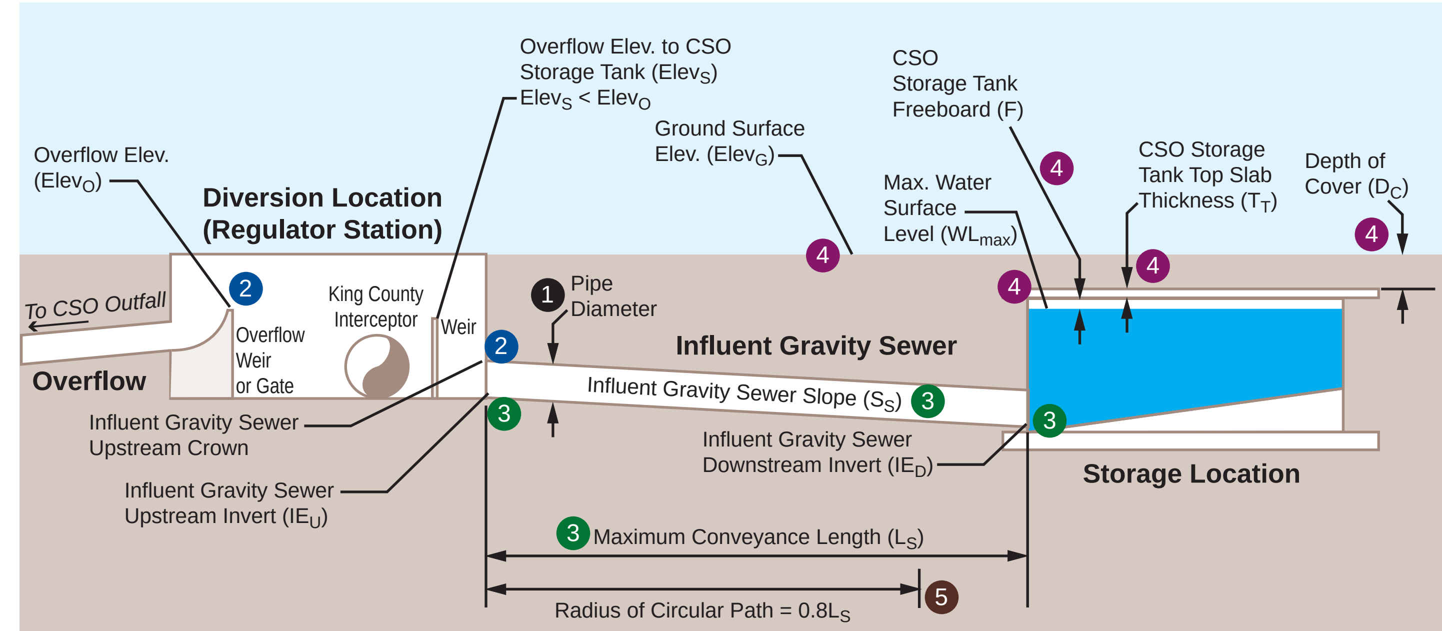
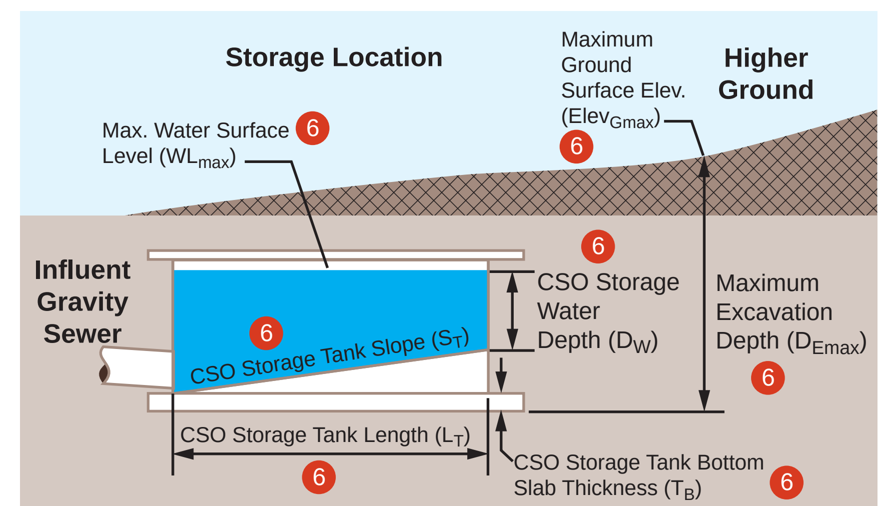
Process Diagram #1: Establishing Approximate Boundary of Potential Sites for CSO Storage Tanks

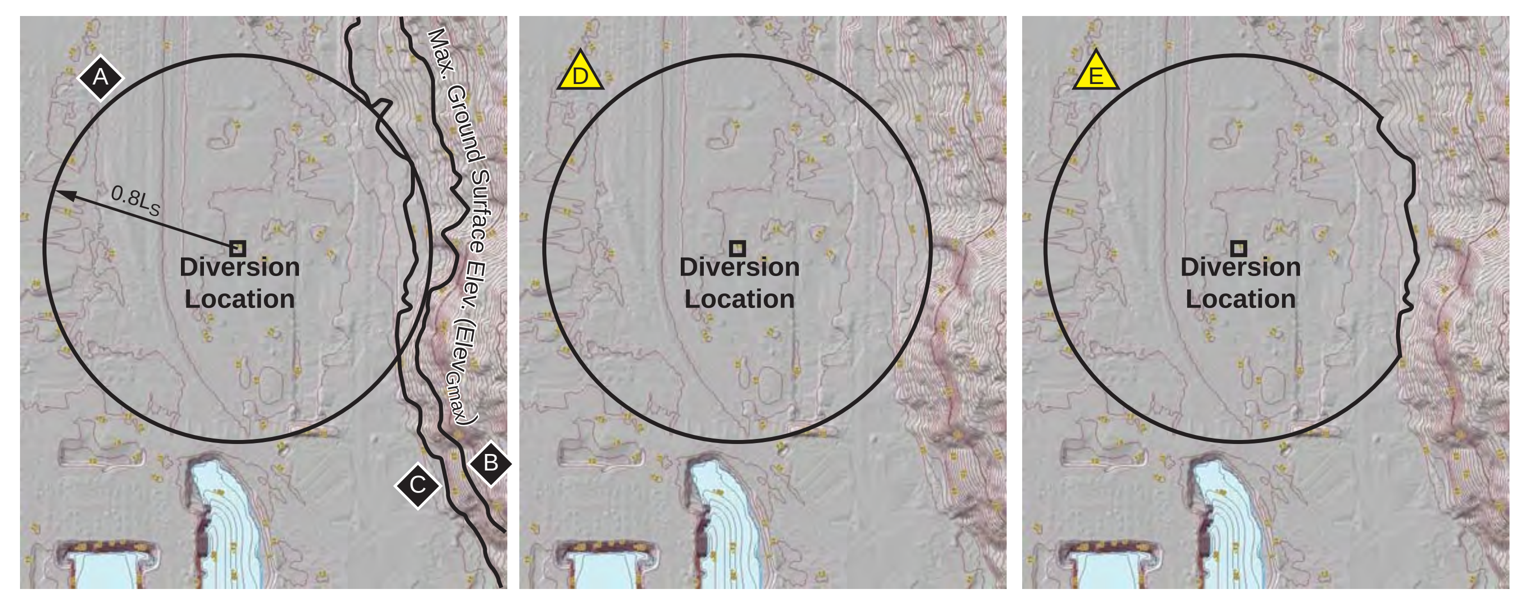




Establish Boundary by Maximum Conveyance Length



Establish Boundary by Maximum Ground Surface Elevation



Note 1:
The diameter of the influent gravity sewer was greater than 48 inches for some alternatives:

- Collaborative alternatives (same slope was assumed as for independent, but pipe diameter was increased due to increased flow from SPU)
- Alternatives in which microtunneling was required
- Alternatives in which the boundary of potential sites was too limited if the slope was increased and diameter was reduced to 48 inches.

Process Diagram #2: Establishing Approximate Boundary of Potential Sites for CSO Storage Tanks When $WL_{max} < Elev_O$

From Process Diagram #1 → **Establishing Boundary for When $WL_{max} < Elev_O$**

↓

Select several ground surface elevations in vicinity of diversion location ($Elev_{G}1$, $Elev_{G}2$, $Elev_{G}3$, etc.; highest to lowest)

↓

Set:
Max. Excavation Depth (D_{Emax}) = 50'
CSO Storage Water Depth (D_W) = 20'
CSO Storage Tank Slope (S_T) = 2%
CSO Storage Tank Length (L_T): *From alternative evaluation*
CSO Storage Tank Bottom Slab Thickness (T_B) = 4'

↓

Estimate Max. Water Surface Level ($WL_{max}n$) for each selected ground surface elevation ($Elev_{G}n$)
$WL_{max}n = Elev_{G}n - D_{Emax} + D_W + (S_T * L_T) + T_B$ (1)

↓

Estimate Influent Gravity Sewer Downstream Invert ($IE_{D}n$) for each selected ground surface elevation at 1' above Max. Water Surface Level: $IE_{D}n = WL_{max}n + 1$ (2)

↓

Set:
Influent Gravity Sewer Upstream Invert (IE_U) = Regulator Station (or Diversion Structure) Invert Elevation
Influent Gravity Sewer Slope (S_S): *As determined in Process Diagram #1* **[Initial Setting]**

↓

Estimate Maximum Conveyance Length ($L_{S}n$) for each selected ground surface elevation
$L_{S}n = (IE_U - IE_{D}n)/S_S$ (3)

↓

Reduce Maximum Conveyance Length by 20% (4)

↓

Map circle with center on diversion location and radius equal to $0.8L_{S}n$ (A)

↓

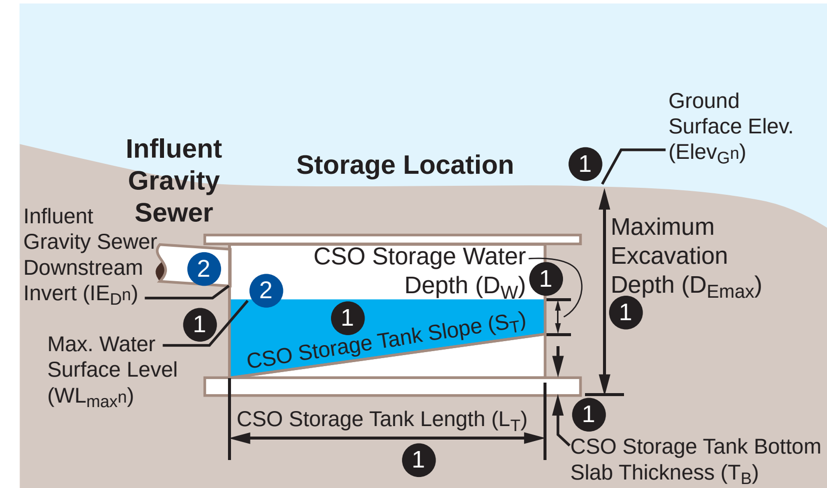
Area too limited?

- YES → Decrease Slope (S_S) *(Use same slope for all ground surface elevations)* → back to "Estimate Maximum Conveyance Length"
- NO ↓

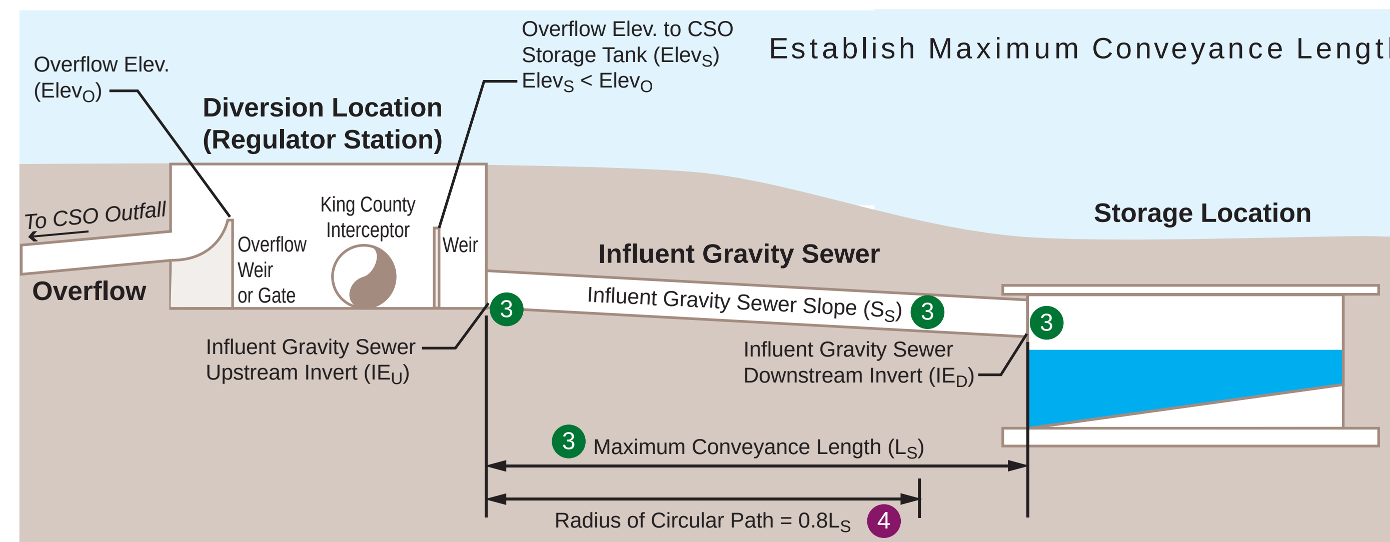
Map contour line for $Elev_{G}n$ (A)

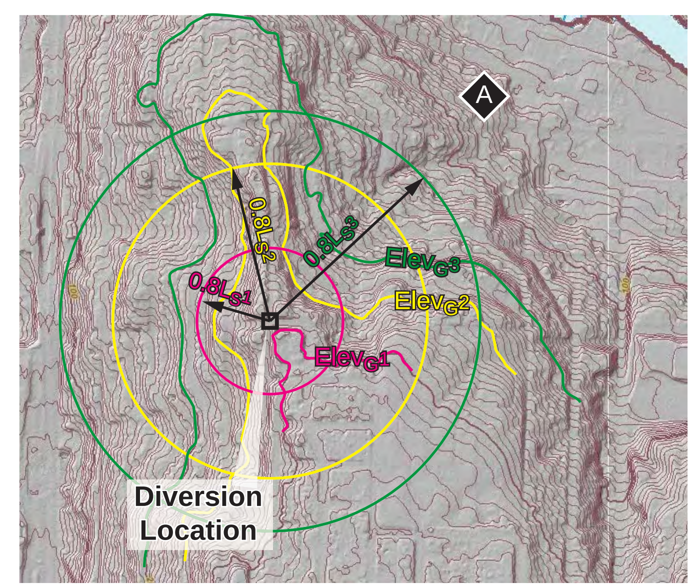
↓

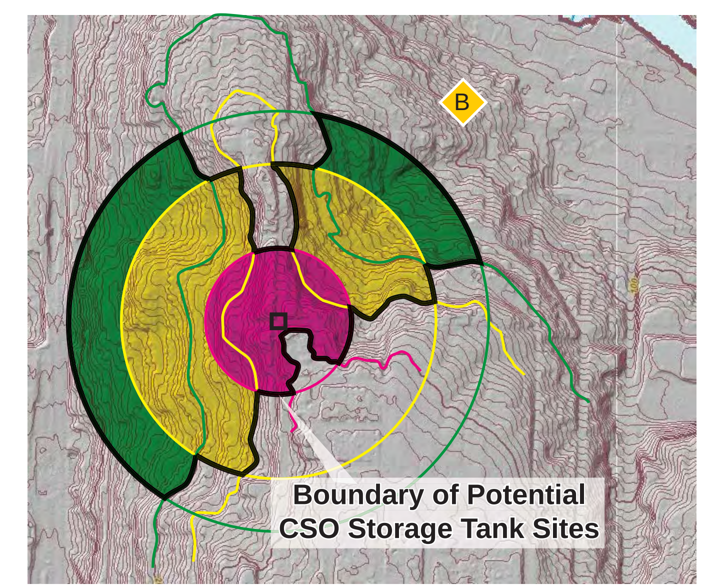
For each circle, potential storage site area is the area inside the circle at elevations equal to or less than the corresponding ground surface elevation ($Elev_{G}1$, $Elev_{G}2$, $Elev_{G}3$, etc.) (B)



Establish Maximum Water Surface Level & Influent Gravity Sewer Downstream Invert







Appendix F.2

Storage Pipe Design Criteria

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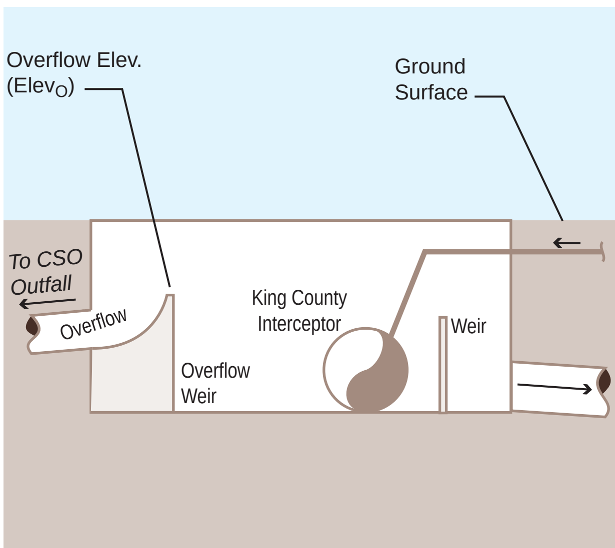
Facility Component	Design Criteria	Footprint Criteria
Offline Storage Pipe	a) Discharge into storage pipe via gravity and pump to drain. b) Maximum Water Surface Level = Existing Overflow Elevation (When Feasible) a. Existing overflow elevation is the water level at which combined sewage is diverted to the existing CSO outfall, either via an overflow weir or outfall gate. b. If site-specific conditions require the offline storage pipe to be constructed deeper, then it may be possible that the maximum water surface level is lower than the existing overflow elevation. These instances will be evaluated on a case-by-case basis to determine if measures are needed to prevent surcharging of storage pipe. c) Pipe Diameter: 12 feet. d) Pipe Wall Thickness: 12 inches. e) Pipe Slope: Minimum 1.0%. f) Pipe Cover Depth: Minimum 3 feet. g) A flushing gate cleaning system with flushing water storage or tipping buckets will be used for flushing. h) Cast-in-place access and flushing structures will be located at upstream and downstream ends of storage pipe (end flushing structure and drain structure). Intermediate cast-in-place access and flushing structure(s) may be needed for longer storage pipes and will be placed at equal spacing to	a) End and Intermediate Flushing Access Structures: 15 ft x 25 ft. b) Drain Structure: 15 ft x 25 ft. c) Valve Vault: 15 ft x 15 ft . d) Assume 18-ft-wide trench. e) Maximum depth of 30 feet (assume cut and cover excavation). f) Assume 90% of storage pipe depth will be used for storage. Reserve 10% depth for headspace.

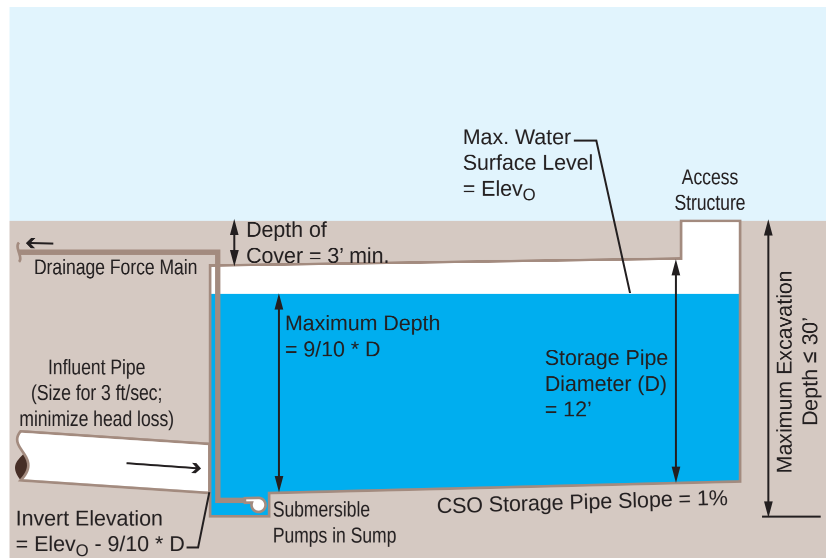
Facility Component	Design Criteria	Footprint Criteria
	allow the same storage volume to be held at each flushing structure. i) Valve vault will house control valves and a common header for drain pumping system.	
Electrical/Controls/Standby Generator Building	**<u>Power Requirements:</u>** -Flushing gate mechanism -Control gate(s) in diversion structure -Drain pumps -Odor control fan -Power panels (lighting, receptacles, etc.) -All equipment, including odor control fan, is on the standby generator.	a) Electrical/Controls/Standby Generator Building Area: 20 ft x 40 ft.
Odor Control Facility	Carbon bed vessel, exhaust fan with acoustical enclosure, mist eliminator, silencer, ductwork with bypass for connection to MOCU. The ventilation rate would be two air exchanges per hour (ac/hr) to control odors, with provisions, including a variable speed drive, for the odor control fan and bypass ductwork for 6 ac/hr to bypass the carbon scrubber and facilitate manned entry into storage facility.	a) Preliminary sizing of odor control unit vessel footprint based on 2 ac/hr for an empty storage pipe with additional footprint included for ancillary equipment. Fire Marshall review may result in greater ventilation rate requirement than 2 ac/hr.
Conveyance Piping to Storage Pipe	a) Discharge into storage pipe via gravity if feasible (free discharge). b) Conveyance piping sized for maximum overflow	

Facility Component	Design Criteria	Footprint Criteria
	rate of events that are at or less than 1-year recurrence by volume based on King County 32-year model simulations. c) Assume velocity is 3 feet per second for sizing conveyance piping	
Force Main (Draining Storage Pipe) and Drain Pumping System	a) Single force main. b) Design to accommodate storage facility drawdown in 12 hours. c) Maintain a velocity between 4 and 10 feet per second.	a) Submersible pumps are located within the drain structure, which is included in the offline storage pipe footprint.
Diversion Structure	a) Locate diversion structure as required to convey combined sewage to storage pipe. b) Diversion structure consists of overflow weirs and gates. Details of operation will be determined during predesign. c) Elevation of new overflow weir that diverts combined sewage to storage pipe is below the existing overflow elevation (water level at which combined sewage is diverted to the existing CSO outfall, either via an overflow weir or outfall gate).	Assume standard 15’ x 15’ footprint.
C2 Water Service	**C2 Water System for Flushing:** Air break tank Booster pumps Backflow preventer	Assume included in equipment building.

CSO Storage Pipe Design Criteria



Diversion Location (Regulator Station)



CSO Storage Pipe

Appendix F.3

Wet-Weather Treatment Facility Design Criteria

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PURPOSE

Develop peak flow rate (MGD) versus footprint (acres) sizing curves for alternative evaluations of wet-weather treatment facilities (WWTFs) using ballasted sedimentation and chemically enhanced primary treatment (CEPT) with lamella plate as part of the King County 2012 CSO Control Program Review (Program Review). Data points are based on existing WWTFs or facilities that are currently in design.

STEP 1) Define Representative Wet-Weather Treatment Facilities.

A representative WWTF for the Program Review includes the unit processes and design criteria presented in Table 1 below.

Table 1. Unit Processes and Design Criteria of Representative Wet-Weather Treatment Facilities

Unit Processes	Design Criteria
Influent Pump Station	1) Assume influent pumping is required for all WWTFs. Include Influent Pump Station in the footprint of WWTF. a. Locate pump station at WWTF to serve as a lift station. Assume influent gravity flow from the regulator station to the WWTF. 2) Influent Pump Station is designed for equalized CSO peak flow rate based on volume of equalization basin.
Screening Systems	1) Ballasted Sedimentation: Fine screens (duty and standby) with washer/compactor and screenings removal 2) CEPT with Lamella Plates: Fine or coarse screens (duty and standby)
Grit Removal System	1) Grit removal (i.e., grit separator) required for Ballasted Sedimentation process 2) CEPT with lamella plates does not require grit removal.
CSO Treatment Process	1) Surface Overflow Rates used for establishing footprint (based on achieving 50% total suspended solids removal): a. **Ballasted Sedimentation:** 57,600 gpd/sf. b. **Chemically Enhanced Primary Treatment with Lamella Plates:** 20,000 gpd/sf. 2) Treatment Capacity a. WWTF is designed for equalized CSO peak flow rates.
Chemical Feed System	Chemical storage and pump feed room
Disinfection System	UV or Chlorination/Dechlorination with Chlorine Contact Tank

Unit Processes	Design Criteria
Electrical/Controls Building	
Generator	
Odor Control Facility	1) Assume vapor phase (carbon scrubber) odor control.
Solids Handling Facility	1) Solids handling facility includes separate sludge storage for ballasted sedimentation consisting of a separate solids thickening clarifier. a. For cost estimating purposes, solids thickening clarifier will be sized with the following assumptions: 1) Design flow = 5% of equalized CSO peak flow rate, 2) surface overflow rate of 800 gpd/sf , and 3) side-water depth of 15 feet. 2) For CEPT processes, a separate solids handling facility is not required because solids storage is available in the larger surface area settling basin of a CEPT facility. Therefore, the solids handling facility footprint was removed or not included for developing the representative footprint curve of wet-weather treatment facilities using CEPT with lamella plates. However, the need for a separate solids handling facility will be evaluated and discussed based on the specific wet-weather treatment facility alternatives.
Other Facilities	1) Account for parking, restrooms, lab, sampling and metering facilities, property setbacks, etc.
CSO Outfall Pipe	1) Existing CSO outfall pipe has adequate capacity to handle the equalized CSO peak flow rates within each uncontrolled CSO basin (independent alternatives). a. Existing CSO outfall, including conveyance piping to outfall, will be used for combined discharge of untreated and treated CSOs. b. Existing CSO outfall will be extended to middle of waterway assuming the same pipe diameter as the existing CSO outfall. Assume open-ended pipe discharge. 2) New CSO outfall will be required for consolidated alternatives in which one CSO basin and outfall handles CSOs from multiple CSO basins. Sizing of new CSO outfall: a. New CSO outfall is sized for equalized CSO peak flow rate. b. New CSO outfall pipe discharges to middle of receiving water body. c. Outfall pipe operates as a pressure pipe during an overflow event. The preliminary outfall assumptions listed above were used during the alternatives development and evaluation process. Refined outfall design concepts and cost estimates were prepared separately from this technical memorandum and are included in *Technical Memorandum 954.03, Preliminary CSO Outfall Concepts Analysis*.

Note: WWTF footprint assumes treated CSOs are diverted to the CSO outfall via gravity, and effluent pumping is not required.

STEP 2) Estimate Footprints of Existing Wet-Weather Treatment Facilities Using Ballasted Sedimentation.

Using existing record drawings and planning-level documents, the approximate footprints of existing wet-weather treatment facilities using ballasted sedimentation were estimated. These existing facilities treat peak flows between 60 MGD and 300 MGD. Table 2 provides brief descriptions and the current status of the existing facilities and projects (i.e., design versus already constructed). The constructed facilities evaluated were part of expansions to existing wastewater treatment facilities. The wet-weather treatment facilities proposed for King County will be satellite facilities and are expected to require additional footprint associated with new facilities.

Table 2. Existing Facilities Used to Establish Footprint Sizing Curves

Facility	Description	Status of Existing Facility or Project
City of St. Joseph Water Protection Facility	60-MGD Ballasted Sedimentation Facility. The ballasted sedimentation facilities, consisting of two parallel 30-MGD trains, are housed in a structure approximately 110 feet by 55 feet. Unit processes include influent pump station, fine screening, grit removal, ballasted sedimentation system, disinfection system (chlorine), and facilities building (electrical/controls).	Design
City of Tacoma, Central Wastewater Treatment Plant	75-MGD Ballasted Sedimentation Facility. The ballasted sedimentation facilities, consisting of two parallel 37.5-MGD trains, are housed in a structure. Unit processes include an influent pump station, fine screening, grit removal, ballasted sedimentation system, solids handling facility, and disinfection system (chlorine).	Constructed
King County, Central Wastewater Treatment Plant	100-MGD Ballasted Sedimentation Facility. As part of the *Task 220.3 CSO Treatment Systems Evaluation and Testing, Final Project Work Plan*, a layout for a ballasted sedimentation facility was developed. Unit processes include an influent pump station, fine screening, ballasted sedimentation system, disinfection system (ultraviolet), and facilities building (odor control, electrical controls, standby generator).	Planning
City of Salem, River Road WWTF	160-MGD Ballasted Sedimentation Facility. The layout of the future expansion of the existing 50-MGD Ballasted Sedimentation Facility was	Constructed

Facility	Description	Status of Existing Facility or Project
	included. Unit processes include an influent pump station, fine screening, ballasted sedimentation system, disinfection system (ultraviolet), and facilities building (odor control and electrical controls).	
City of Toledo, Bayview WWTF	232-MGD Ballasted Sedimentation Facility. The ballasted sedimentation facilities are part of a 400-MGD wet-weather treatment facility expansion, consisting of 60-MGD trains. Unit processes include fine screening, grit removal, ballasted sedimentation system, solids handling facility, disinfection system, and facilities building (electrical controls).	Constructed
Alcosan Facility	300-MGD Ballasted Sedimentation Facility. The ballasted sedimentation facility is a new wet-weather treatment facility. Unit processes include an influent pump station, fine screening, grit removal, ballasted sedimentation system, solids handling facility, disinfection system (chlorine), and facilities building (electrical controls).	Design

STEP 3) Adjust Footprints of Existing Facilities to Develop Representative Wet-Weather Treatment Facility Footprints

Common elements of the existing facilities (Table 1) include fine screening, ballasted sedimentation system, and a disinfection system. However, there were unit processes identified in the representative wet-weather treatment facility footprint (Table 2) that were not included in the existing facilities evaluated. Therefore, the footprints of the existing facilities were adjusted to include the unit processes identified as part of a representative CSO treatment process. Table 3 summarizes the percent adjustments assigned to each unit process that were used to normalize the footprints of the existing facilities.

Table 3. Percent Adjustments Assigned to Each Unit Process for Normalization of Footprints

Percent Adjustments of Total Footprint	Unit Process
5 percent	Influent Pump Station
5 percent	Grit Removal System
15 percent	Solids Handling Facility
5 percent	Odor Control Facility
5 percent	Electrical/Controls Building
10 percent	Generator
50 percent	Other Facilities (Restrooms/lab/site buffer)

STEP 4) Develop Footprint Sizing Curve for Wet-Weather Treatment Facilities Using Ballasted Sedimentation.

The footprint sizing versus wet-weather treatment facility peak flow rate data from the normalized footprints of the existing facilities were plotted, and a best-fit curve and equation was developed to use for the wet-weather treatment facilities using ballasted sedimentation associated with the Program Review. Figure 1 illustrates the footprint sizing curve for ballasted sedimentation.

STEP 5) Develop Footprint Curves for Wet-Weather Treatment Facilities Using CEPT with Lamella Plates.

Representative footprint sizing versus wet-weather treatment facility peak flow rate curves were developed similarly for the wet-weather treatment facilities using CEPT with lamella plates based on the normalized footprint data of existing facilities evaluated for ballasted sedimentation. The following adjustments were made to the normalized footprints:

a) Add footprint associated with the CEPT system to the normalized ballasted sedimentation footprint.

- Add footprint for chemical mixing tanks – Footprint for the chemical mixing tanks was based on a detention time of 8 minutes total through the mixing and flocculation tank and an assumed depth of 15 feet.

For example, the footprint of the chemical mixing tank for River Road WWTF (160 MGD) was based on approximately an 888,900-gallon tank required for a detention time of 8 minutes, which equates to approximately 7,920 sf based on a 15-foot-deep tank. The chemical mixing tank footprint was multiplied by 1.5 for contingency.

- Add footprint for increased settling basin – Calculate additional footprint due to CEPT with lamella plates at a lower surface overflow rate (SOR) of 20,000 gpd/sf compared to the SOR of 57,600 gpd/sf for ballasted sedimentation.

  For example, the footprint associated with the ballasted sedimentation settling basin for River Road WWTF (160 MGD) was calculated based on a SOR of 57,600 gpd/sf, which equates to approximately 2,778 sf. The footprint associated with the CEPT with lamella plates settling basin for River Road WWTF (160 MGD) was then calculated based on a SOR of 20,000 gpd/sf, which equates to approximately 8,000 sf. This footprint is then multiplied by 1.5 for contingency, resulting in a footprint of approximately 12,000 sf for the CEPT with lamella plates settling basin.

b) Remove footprints of unit processes associated with the wet-weather treatment facility using ballasted sedimentation that would not be part of the CEPT unit processes.

- Remove grit removal facility footprint – Grit removal is not required in a CEPT facility. Footprint for grit removal was removed based on the existing grit removal footprint of the existing facility or based on the adjustment percentage of 5 percent of the total facility footprint.
- Remove solids handling facility footprint - Typically a separate solids handling facility is not required because solids storage is available in the larger surface area settling basin of a CEPT facility. Therefore, the solids handling facility footprint was removed for developing the representative footprint sizing curve of wet-weather treatment facilities using CEPT with lamella plates. However, the need for solid handling will be evaluated and discussed based on the specific wet-weather treatment facility alternatives.
- Apply a contingency of 1.5 to the estimated footprint.

The footprint sizing versus wet-weather treatment facility peak flow rate data from the adjusted footprints for wet-weather treatment facilities using CEPT with lamella plates were plotted, and a best-fit curve and equation was developed to use for the wet-weather treatment facilities using CEPT with lamella plates associated with the Program Review. Figure 2 illustrates the footprint sizing curve for CEPT with lamella plates.

Figure 1 and Figure 2 present the WWTF peak flow rate versus footprint with best-fit curves for ballasted sedimentation and CEPT with lamella plates, respectively. The equations presented in these figures will be used in the development and evaluation of WWTF final alternatives associated with this Program Review.

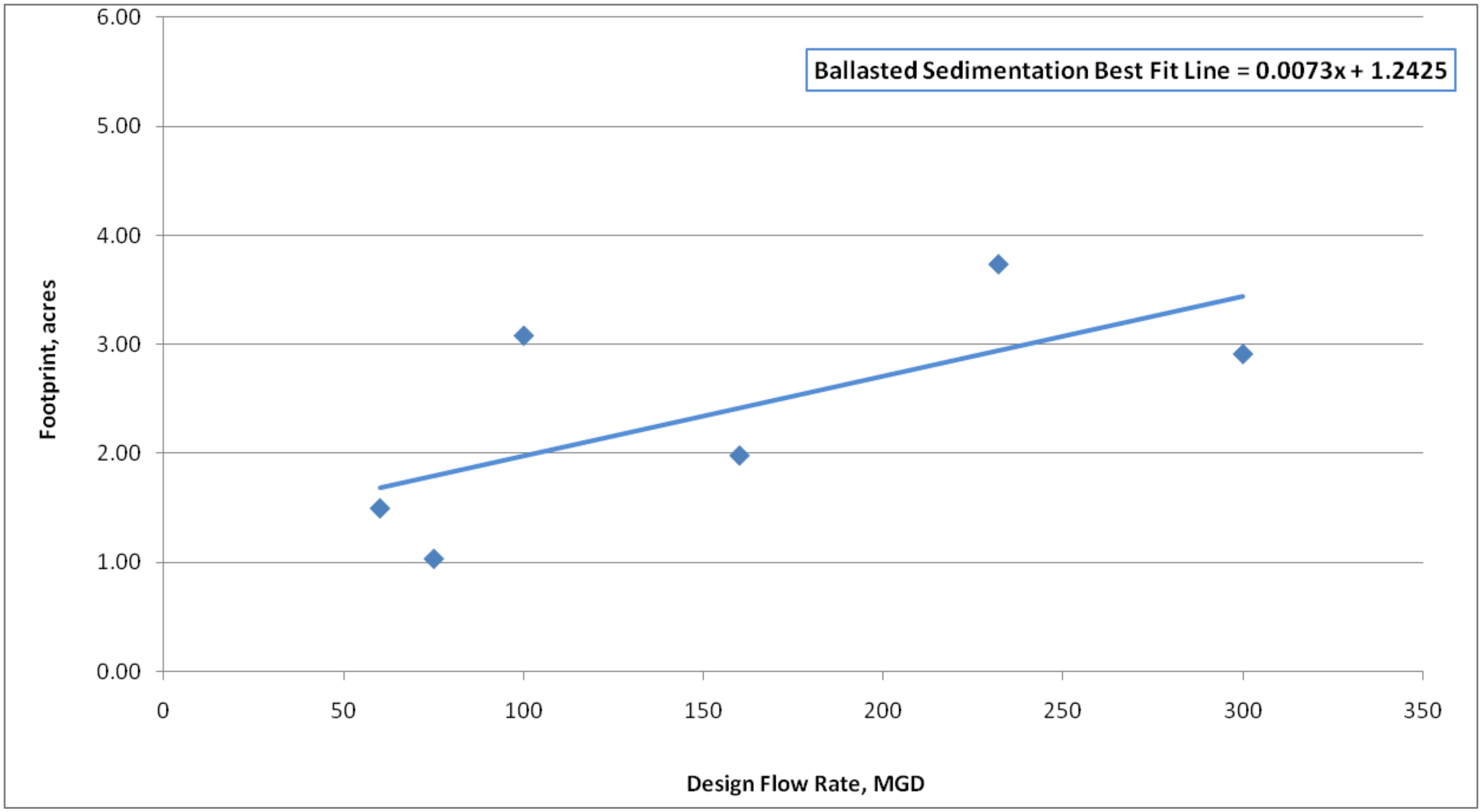


Figure 1. Footprint Sizing Curves for Ballasted Sedimentation

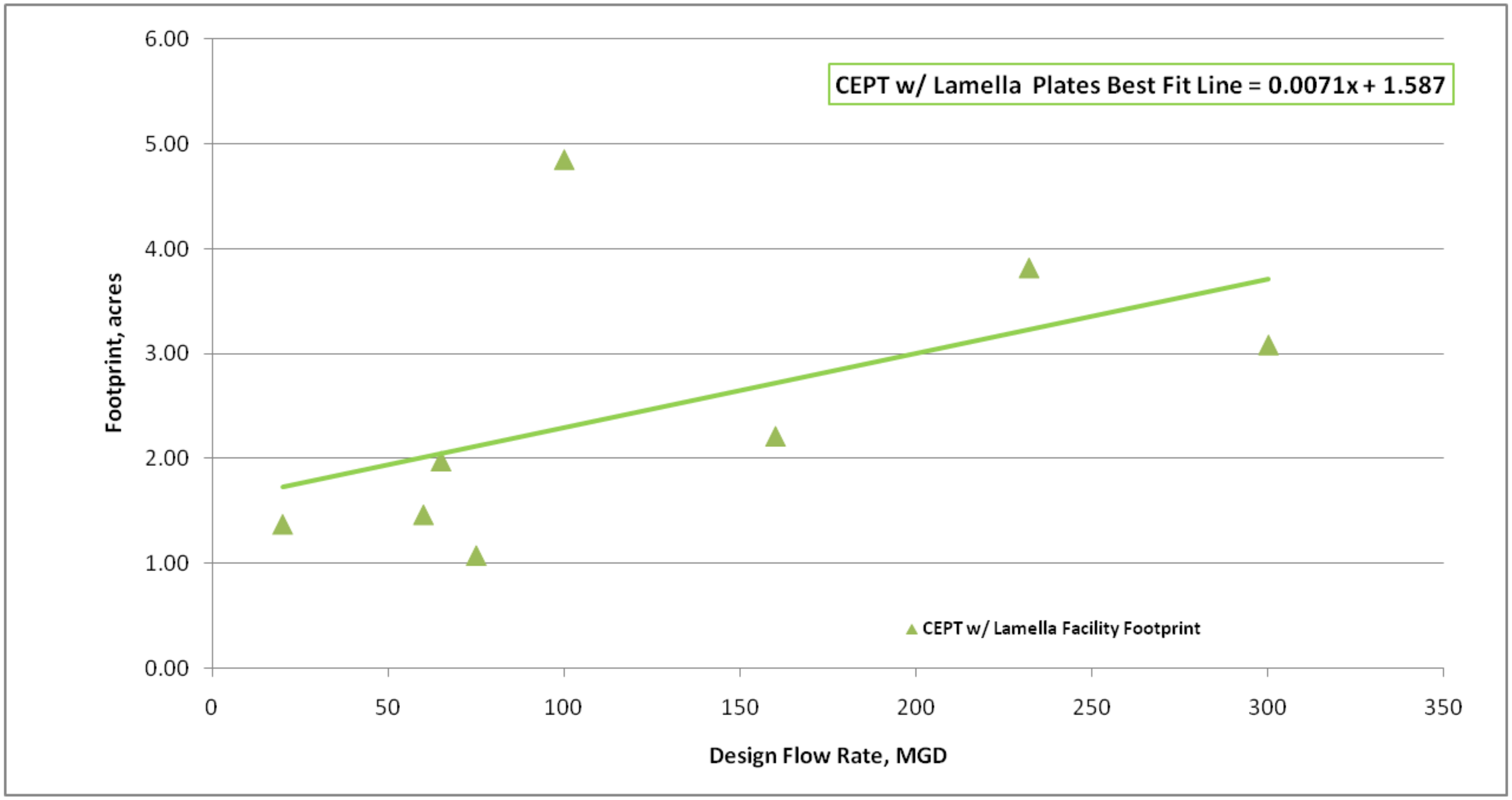
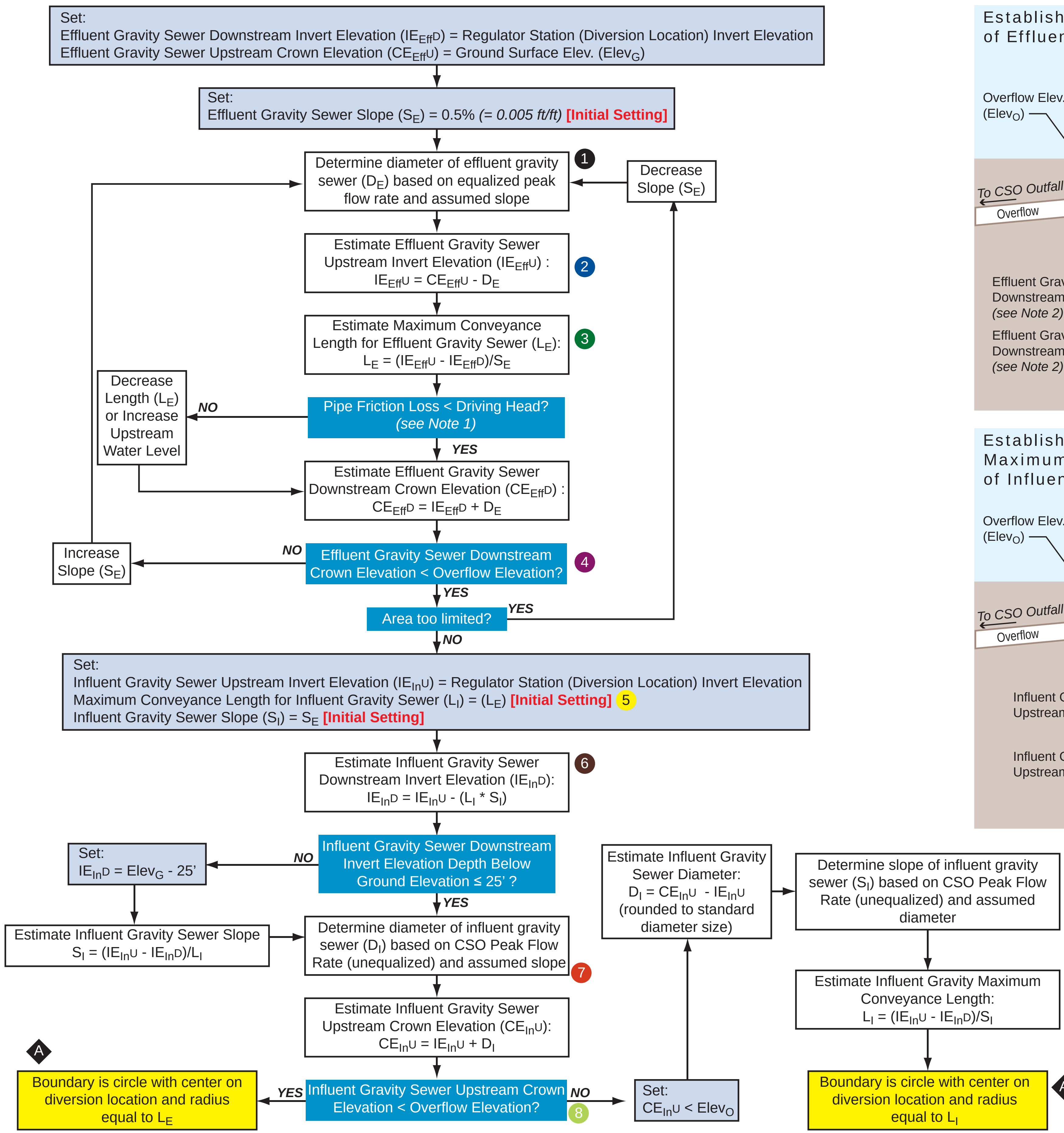
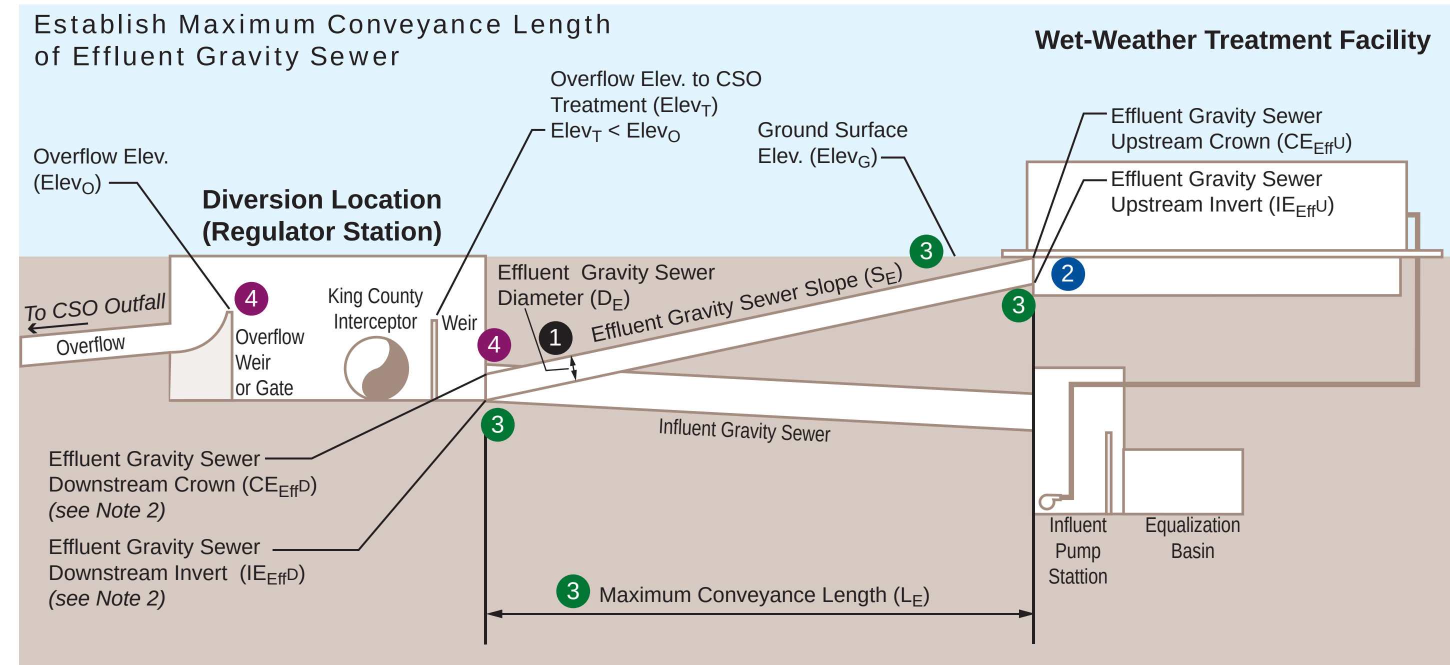
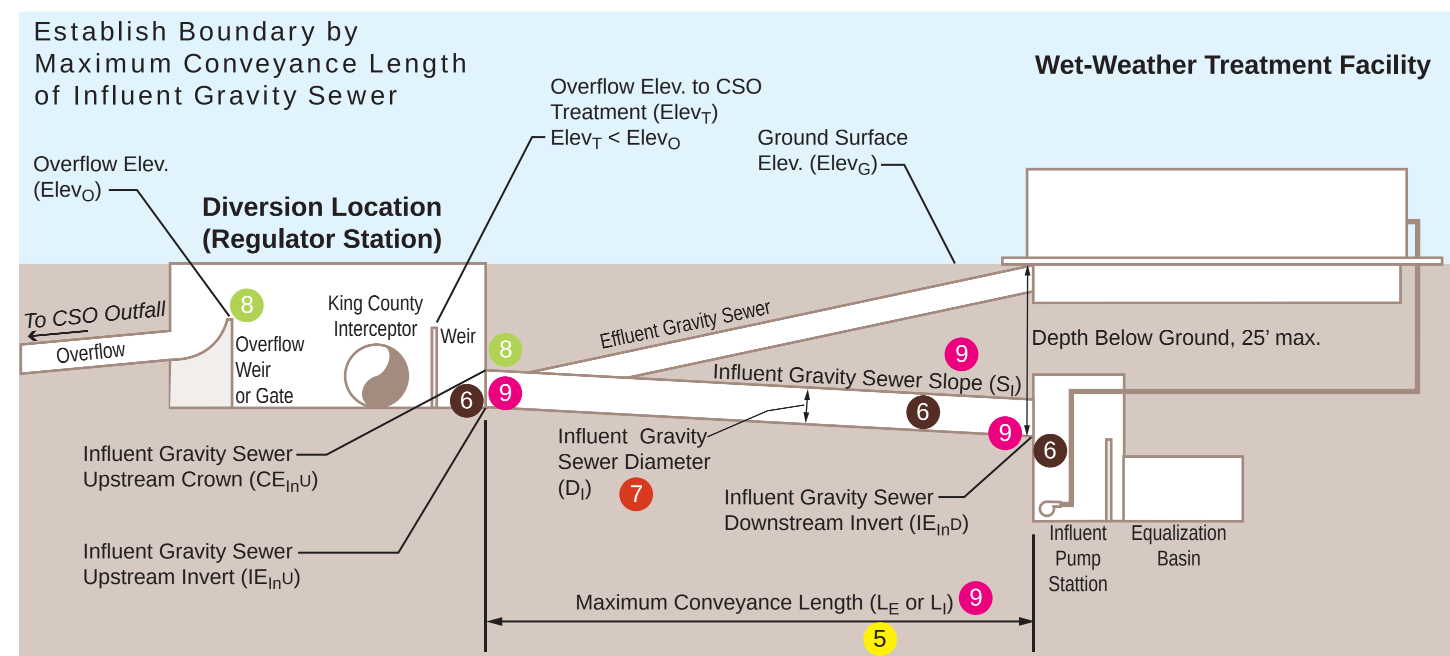


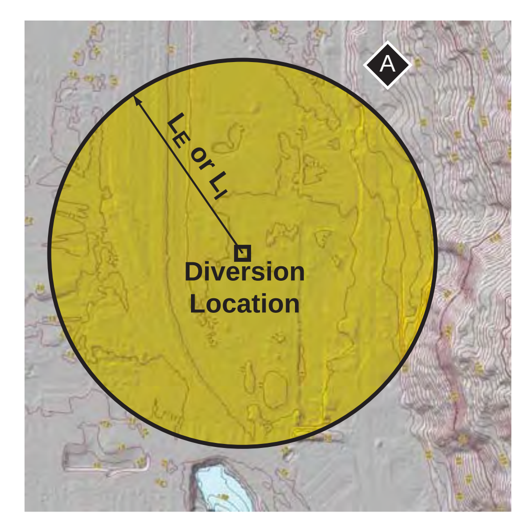
Figure 2. Footprint Sizing Curves for Chemically Enhanced Primary Treatment with Lamella Plates

Process Diagram #3: Establishing Approximate Boundary of Potential Sites for Wet-Weather Treatment Facilities









Note 1: Driving head is the pressure force associated with the difference between the upstream and downstream water levels of a pipeline. For this analysis, the upstream water level is 4 feet above the ground elevation and the downstream water level is the high tide level, including any potential future rise in sea level .

Note 2: Effluent Gravity Sewer shown connected to regulator station for simplicity; actual connection would be to CSO outfall.

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Appendix F.4

Optimum Capacity Assessment

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Appendix F.4

Optimum Capacity Assessment

Step 1: Develop Flow-Volume Curves

King County created flow-volume curves for the optimum capacity assessment. The flow-volume curves represent different combinations of treatment peak flow rate and equalization basin volume that result in an average of one untreated discharge per outfall per year.

Details regarding the methodology of these analyses as well as the flow-volume curves for each treatment alternative are presented in a technical memorandum (TM) that is presented at the end of this section (TM referred to as *Flow-Volume Curves for CSO Treatment Alternatives*).

One of the treatment alternatives (consolidated King St and Kingdome wet-weather treatment facility (WWTF)) was not included in the TM. The flow-volume curve and corresponding best-fit equation for the consolidated King St and Kingdome WWTF was prepared separately from the TM and is presented in Figure F.4-1 below.

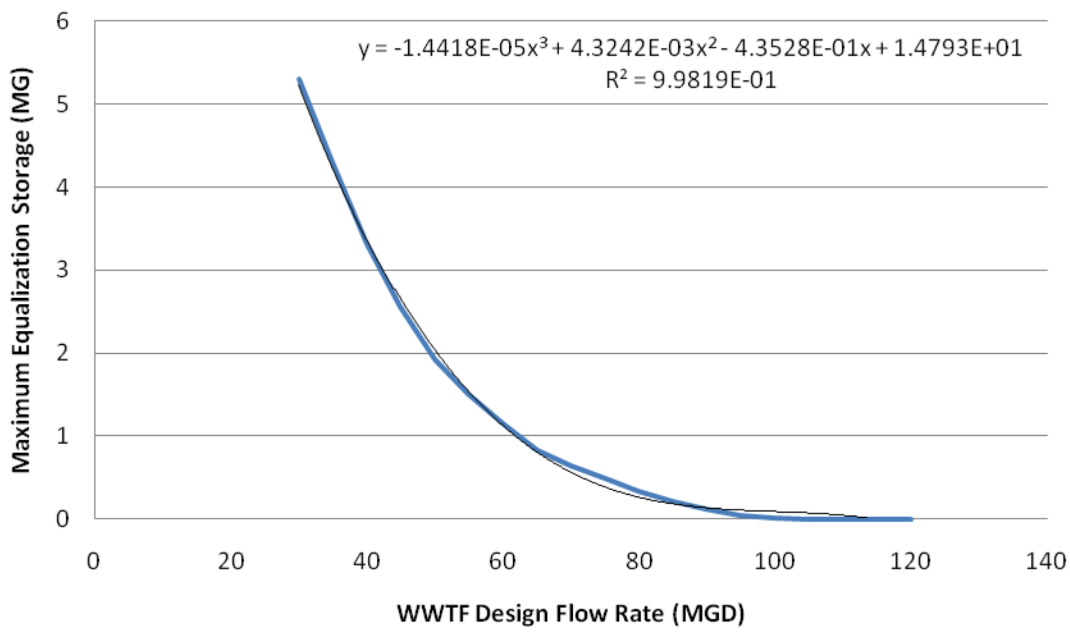

Figure F.4-1. Flow-Volume Curve for Consolidated King St and Kingdome WWTF

King County
Department of Natural Resources and Parks
Wastewater Treatment Division
King Street Center, KSC-NR-0500
201 South Jackson Street
Seattle, WA 98104-3855

MEMO

Date: October 28, 2010

TO: Karen Huber

CC: Bruce Crawford, Bob Swarner
Dan Pecha, Carrie Murillo-Oaks, HDR

FM: Bruce Nairn

RE: Flow – Volume Curves for CSO treatment alternatives

CREATING RESOURCES FROM WASTEWATER

1 Introduction

This memo documents the flow-volume curves created for the 2012 CSO program review. A flow-volume curve represents the combinations of treatment capacity (flow) and storage volume that result in a constant number of untreated overflows.

Different operational strategies are possible for a treatment facility. This analysis assumed that flow would be passed to the treatment facility until the treatment capacity was reached, then flow in excess of the treatment capacity would fill the storage volume. The treatment facility would operate at maximum capacity until the storage volume was emptied. Other operational strategies could change the flow-volume relationship and should be specifically analyzed.

2 Methods

A python module (wxStorage.py) was written to simulate the operational strategy on a given hydrograph. Given a range of maximum flow rates, the code solved for the required storage volume to reduce the number of events that would have to be bypassed around the facility to a specified number. This calculated volume for each discharge rate was output to a file. In addition, the volume required to have one discharge less than the specified number was also output to the file. A storage volume between these two volumes will result in the specified number of bypassed events.

The hydrographs used in this analysis were provided by Bruce Crawford on 10/18/2010 and are located on //wtddata/common/CrawfordB/consolidated_timeseries . The following hydrographs were analyzed:

- Brandon CSO
- Michigan CSO
- Combined Brandon + Michigan CSO
- Hanford CSO
- Lander CSO
- Kingdome CSO
- King CSO
- Combined Hanford + Lander CSO
- Combined Hanford + Lander + Kingdome CSO
- Combined Hanford + Lander + Kingdome + King CSO

The hydrographs comprise a 32-year model run from 1/1/1978 to 12/31/2009. The analysis was set to one event per year, or 32 events per hydrograph.

3 Results

The flow-storage volumes curves for 1 by-pass event per year are summarized in the attached Excel file (FlowVolumeSummary.xls). The curves are presented graphically below. In these figures the minimum storage volume (blue) is the minimum storage volume that results in 32 by-pass events (1/year). The maximum storage volume (red) is the maximum storage volume that results in 32 by-pass events (1/year).

3.1 Brandon CSO

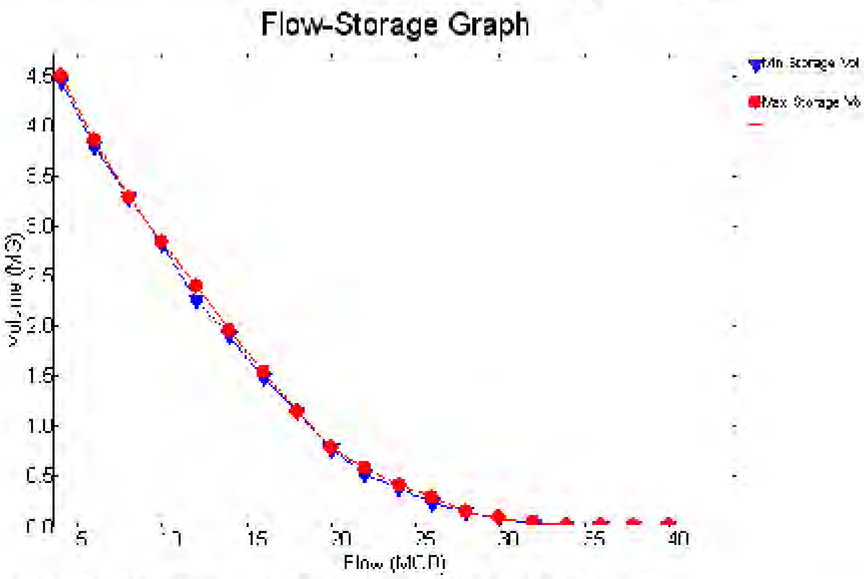

Figure 1. Flow – Storage Volume relationship for Brandon CSO.

3.2 Michigan CSO

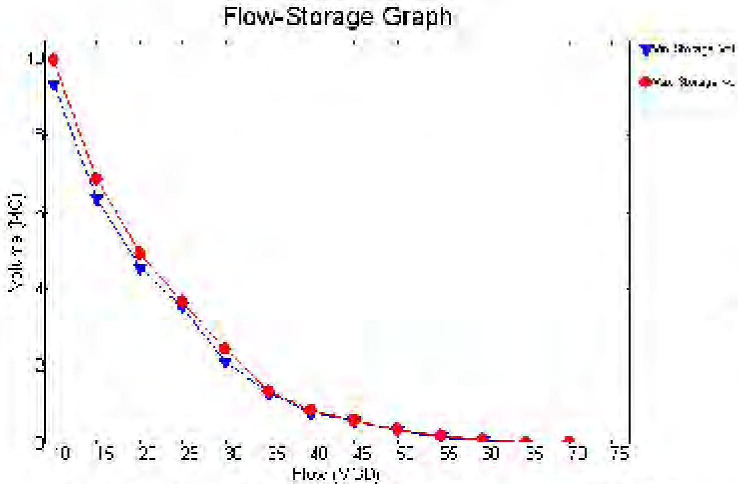

Figure 2. Flow – Storage Volume relationship for Michigan CSO.

3.3 Combined Brandon + Michigan CSO

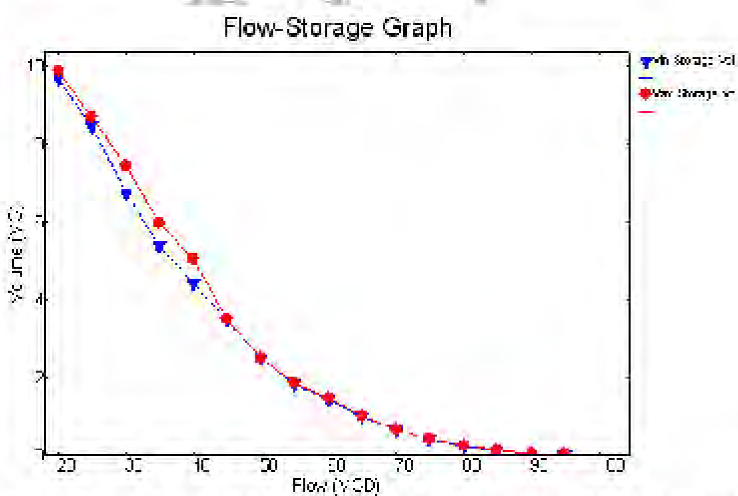

Figure 3. Flow – Storage Volume relationship for a combined Brandon + Michigan CSO.

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3.4 Hanford CSO

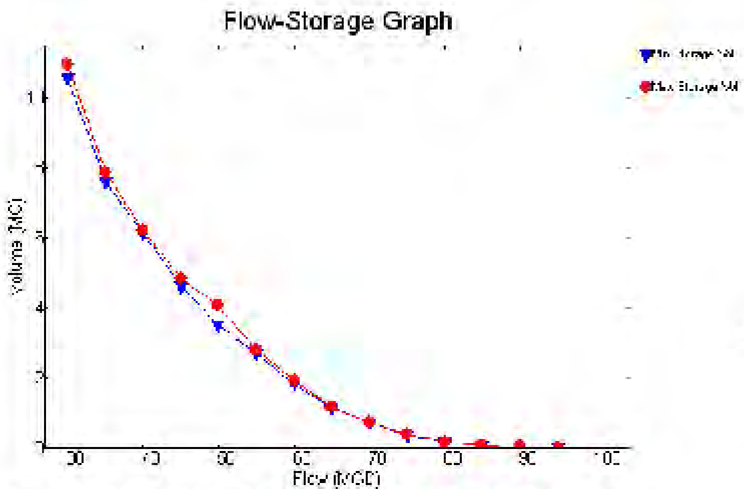

Figure 4. Flow – Storage Volume relationship for Hanford CSO.

3.5 Lander CSO

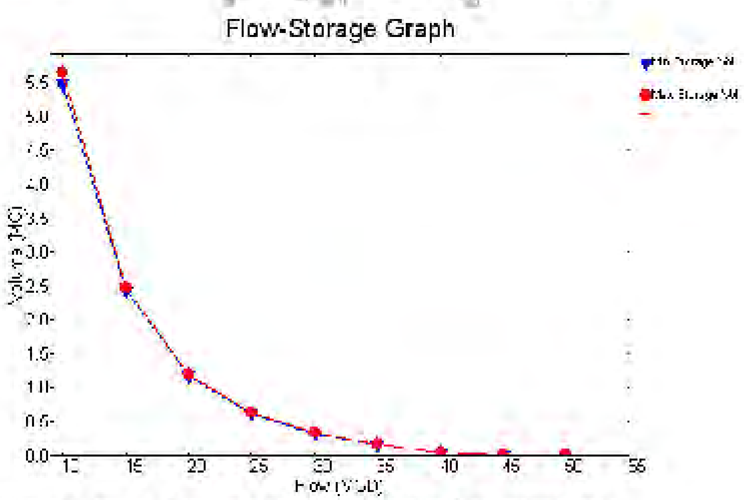

Figure 5. Flow – Storage Volume relationship for Lander CSO.

3.6 Kingdome CSO

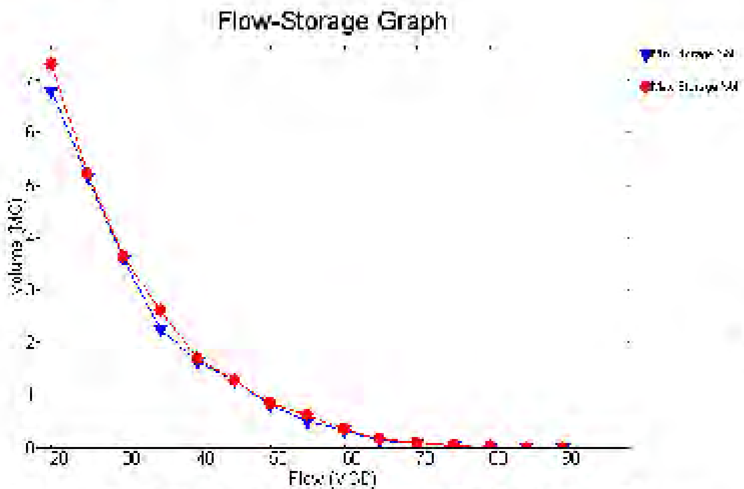

Figure 6. Flow – Storage Volume relationship for Kingdome CSO.

3.7 King CSO

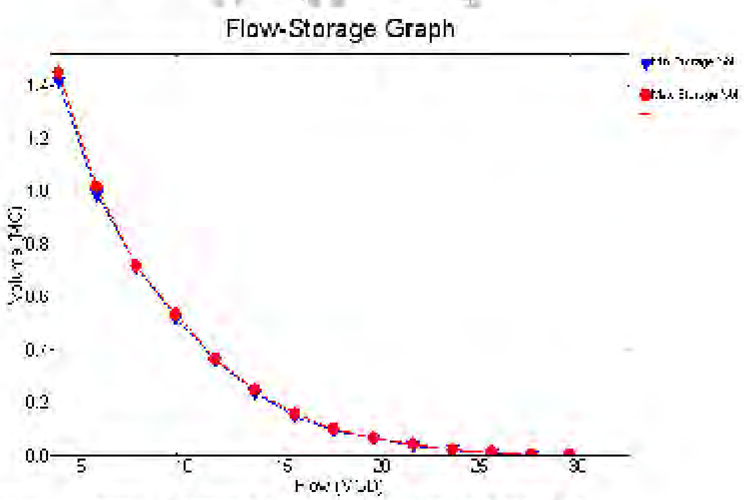

Figure 7. Flow – Storage Volume relationship for King CSO.

3.8 Combined Hanford + Lander CSO

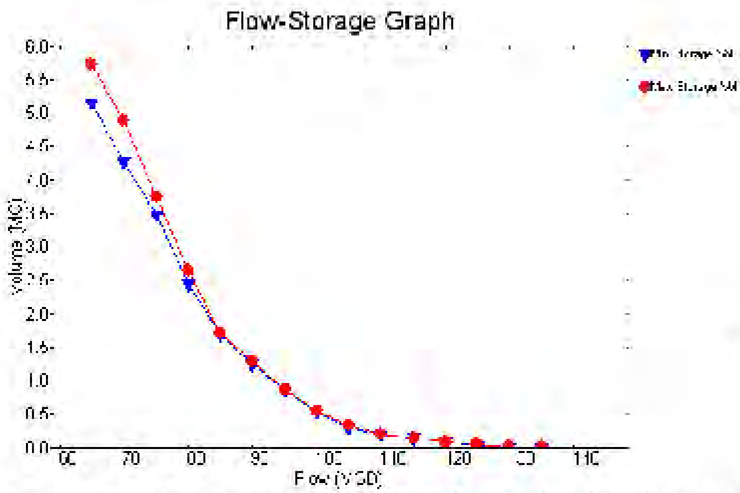

Figure 8. Flow – Storage Volume relationship for a combined Hanford + Lander CSO.

3.9 Combined Hanford + Lander + Kingdome CSO

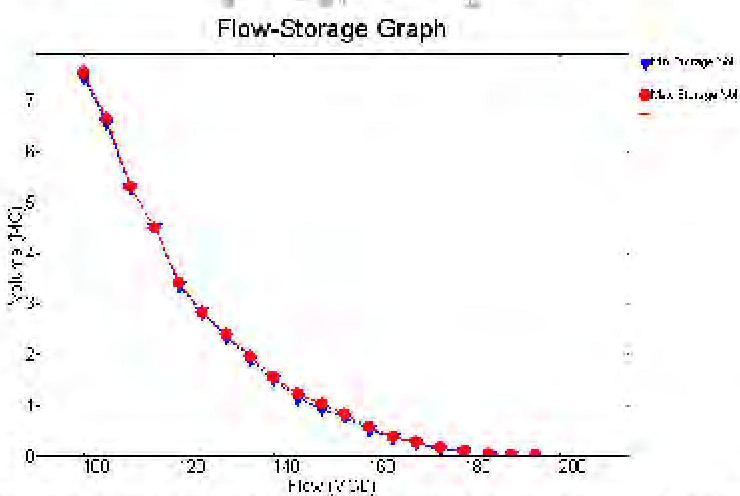

Figure 9. Flow – Storage Volume relationship for a combined Hanford + Lander + Kingdome CSO.

3.10 Combined Hanford + Lander + Kingdome + King CSO

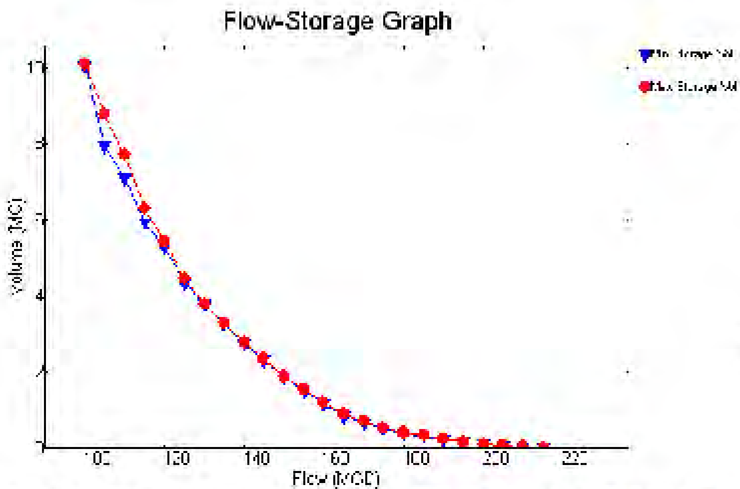

Figure 10. Flow – Storage Volume relationship for a combined Hanford + Lander + Kingdome + King CSO.

Step 2: Develop Footprint Sizing Curves and Estimate Property Costs

Footprint Sizing of Wet-Weather Treatment Facilities

Representative footprint sizing versus treatment peak flow rates curves were developed to establish planning-level footprints for the various alternatives. The methodology used to develop the footprint sizing curves for wet-weather treatment facilities using ballasted sedimentation and CEPT with lamella plates is described in Appendix F.3. The footprint sizing curve and corresponding equations for wet-weather treatment facilities (for both CSO treatment processes) is also presented in Appendix F.3.

Footprint Sizing of Equalization Basins

Representative footprint sizing versus equalization basin volume were developed to establish planning-level footprints for the treatment alternatives.

The footprint sizing curve for equalization basins (volume versus footprint) was developed based on the assumptions presented in the Storage Tank Design Criteria (Appendix F.1), assuming a 3:1 length-to-width ratio and a side water depth of 20 feet. The equalization basin footprint sizing curve and corresponding best-fit equation is presented in Figure F.4-2.

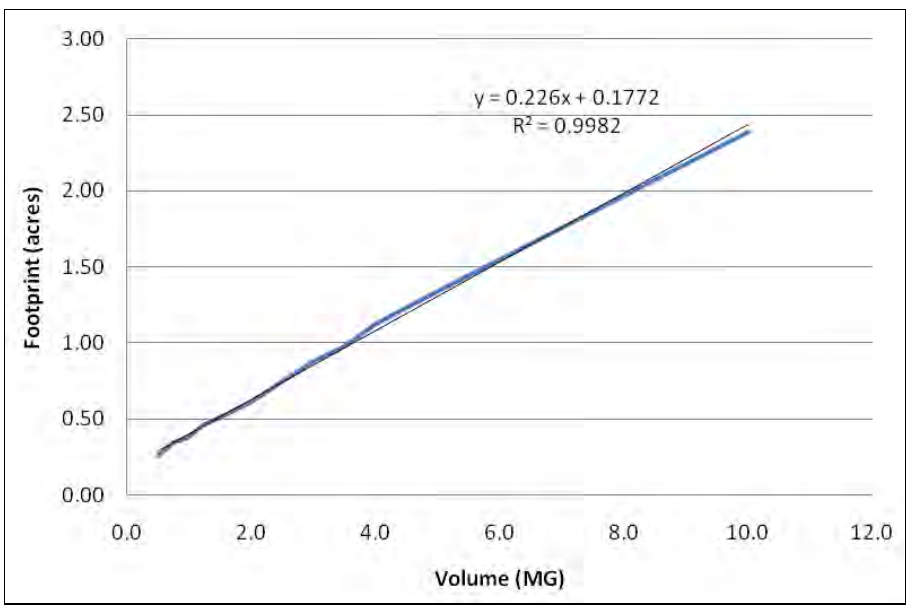

Figure F.4-2. Equalization Basin Footprint Sizing Curve

Estimating Property Costs

Property costs were estimated by multiplying the corresponding footprint sizes of treatment facilities and equalization basins by the property and building unit cost ($/SF) of the CSO basin where the treatment facility is located. Property and building unit costs of the uncontrolled CSO basins are presented in Appendix C of the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities*.

Step 3: Develop Construction Cost Curves

Construction cost curves were developed for equalization basins and wet-weather treatment facilities using ballasted sedimentation or chemically enhanced primary treatment with lamella plates to estimate construction costs of the different facilities. These cost curves were used to determine the most cost-effective relative sizing of treatment and equalization.

Equalization Basin Cost Curve

Using the same methodology as what is presented in Section 2.4.1 of the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities* for storage tanks, a construction cost curve (equalization basin volume versus construction cost) was developed to estimate construction costs for equalization basins. The construction cost curve and corresponding best-fit equation for equalization basins is presented in Figure F.4-3 below. To develop construction cost estimates of equalization basins at varying volumes, use the curve or equation for total construction costs in Figure F.4-3.

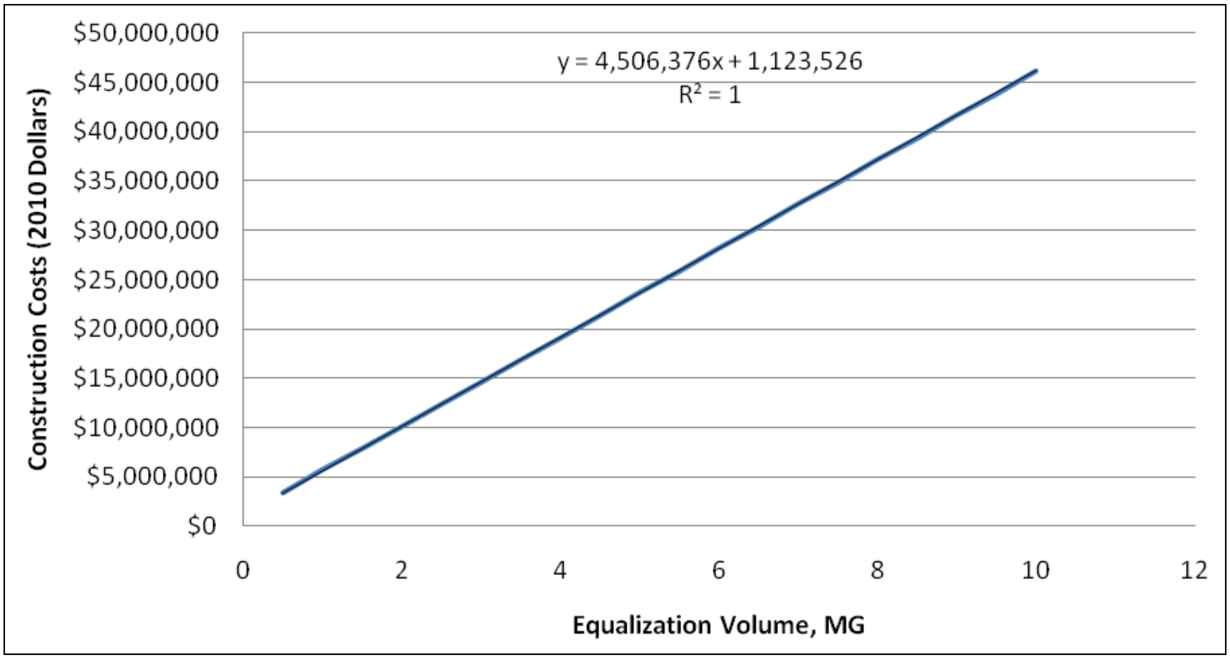

Figure F.4-3. Construction Costs for Equalization Basins

Ballasted Sedimentation Cost Curve

A construction cost curve for wet-weather treatment facilities using ballasted sedimentation was developed as part of the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities.*

Figure F.4-4 shows the cost curves developed for ballasted sedimentation. The figure shows curves for individual components of the treatment facility, as well as total estimated construction cost. Table F.4-1 provides best-fit equations for each curve. To develop construction cost estimates of wet-weather treatment facilities using ballasted sedimentation at varying peak flow rates, use the curve or equation for total construction costs in Figure F.4-4 or Table F.4-1.

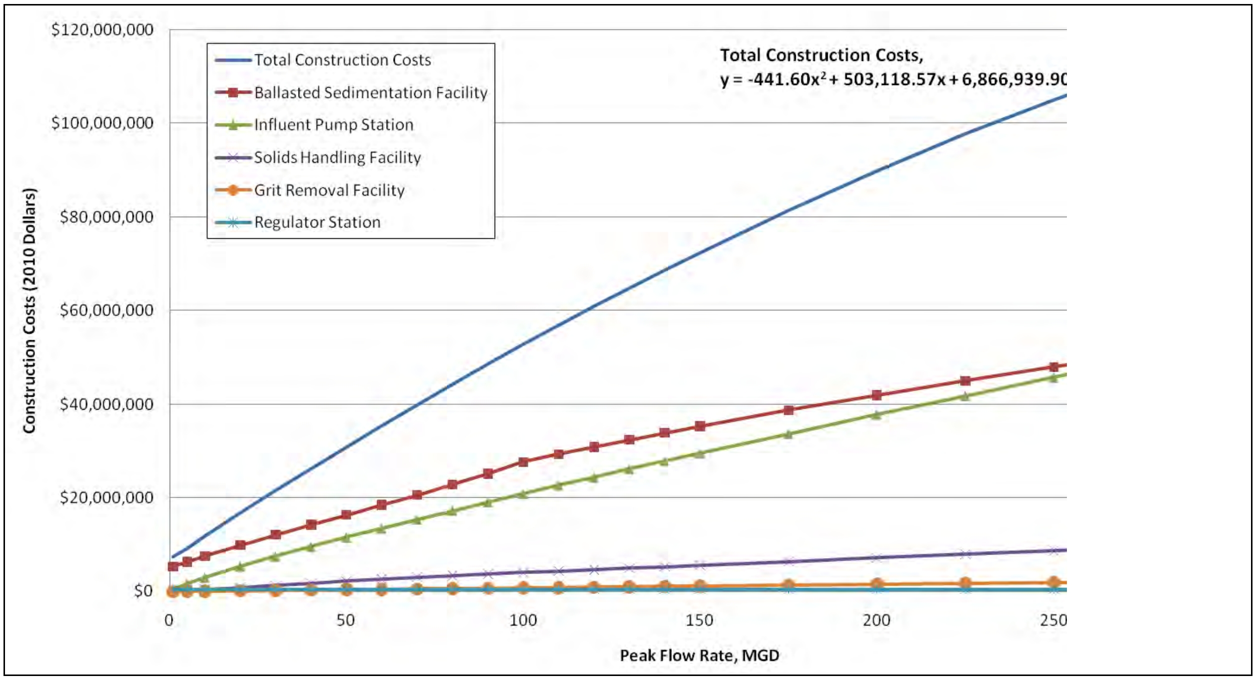

Figure F.4-4. Construction Costs for WWTFs Using Ballasted Sedimentation

Table F.4-1. Cost Equations for WWTFs Using Ballasted Sedimentation

Component	Construction Cost Equation[a] (2010 Dollars)
Ballasted Sedimentation	Construction Cost = $-308.06x^2 + 248{,}995.12x + 5{,}012{,}751.25$
Influent Pump Station	Construction Cost = $-133.54x^2 + 212{,}088.62x + 979{,}951.34$
Solids Handling Facility	Construction Cost = $34{,}273.93x + 389{,}237.31$
Grit Removal Facility	Construction Cost = $7{,}760.90x$
Regulator Station	Construction Cost = 485,000
Total of All Components	Construction Cost = $-441.60x^2 + 503{,}118.57x + 6{,}866{,}939.90$

a. x = Peak flow rate in million gallons per day

Cost Curve for CEPT with Lamella Plates

A construction cost curve for wet-weather treatment facilities using chemically enhanced primary treatment with lamella plates was developed as part of the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities*. Separate solids handling facility construction costs and associated property costs were not incorporated into the cost curve or optimum capacity assessment when determining the most cost-effective combination of equalization and treatment. Solids handling was evaluated separately as discussed in the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities.*

Figure F.4-5 shows the cost curves developed for a wet-weather treatment facility using CEPT with lamella plates. The figure shows curves for all individual components of the treatment facility except the separate solids handling facility, as well as total estimated construction cost for the components shown. Table F.4-2 provides best-fit equations for each curve. For the optimum capacity assessment, to develop construction cost estimates of wet-weather treatment facilities using CEPT with lamella plates at varying peak flow rates, use the curve or equation for total construction costs in Figure F.4-5 or Table F.4-2.

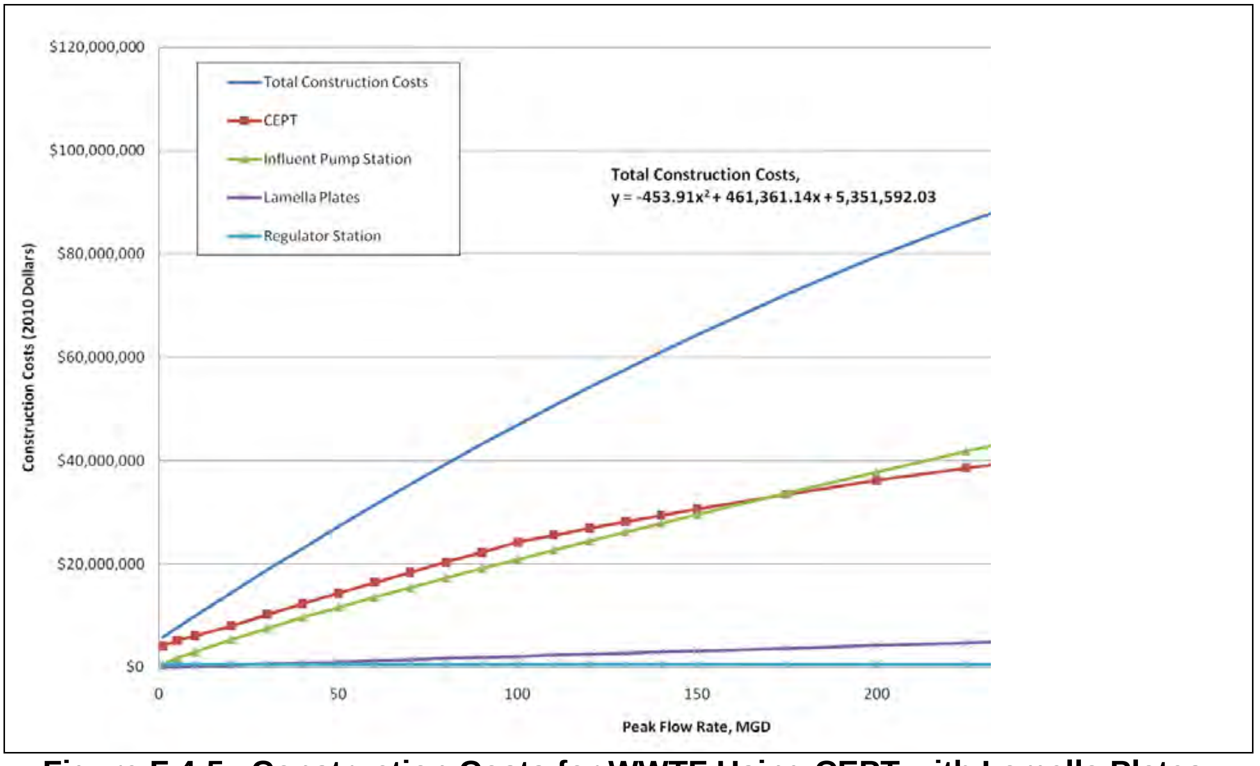

Figure F.4-5. Construction Costs for WWTF Using CEPT with Lamella Plates, Excluding Solids Handling Facilities

Table F.4-2. Cost Equations for WWTF Using CEPT with Lamella Plates, Excluding Solids Handling Facility

Component	Construction Cost Equation[a] (2010 Dollars)
CEPT	Construction Cost = $-320.37x^2 + 228{,}220.40x + 3{,}886{,}640.69$

Component	Construction Cost Equation[a] (2010 Dollars)
Influent Pump Station	Construction Cost = $-133.54x^2 + 212{,}088.62x + 979{,}951.34$
Lamella Plates	Construction Cost = $21{,}052.12x$
Regulator Station	Construction Cost = 485,000
Total (Excluding Solids Handling)	Construction Cost = $-453.91x^2 + 461{,}361.14x + 5{,}351{,}592.03$

a. x = Peak flow rate in million gallons per day

Step 5: Identify Treatment Peak Flow Rate and Equalization Basin Volume with Lowest Costs

The total property costs and construction costs of treatment facilities and equalization basins were summed for each treatment alternative and peak flow rate. The total costs of varying treatment peak flow rates were plotted on a single graph for each alternative, and the treatment peak flow rate and corresponding equalization basin volume with the lowest total costs was identified. These represent the most cost-effective combination of equalization and treatment for the treatment alternative to be included in the alternatives evaluation and Program Review. The total cost curves and treatment peak flow rate for each treatment alternative is presented in the following sections. The most cost-effective combination of equalization and treatment for each treatment alternative is also summarized in Table F.4-3 below.

Table F.4-3. Treatment and Equalization Design Capacities for Wet-Weather Treatment Facility Alternatives

Alternative	CSO Treatment Process	Treatment Peak Flow Rate (MGD)	Equalization Basin Volume (MG)
Kingdome	Ballasted Sedimentation	48	0.87
	CEPT with Lamella Plates	49	0.79
Lander St	Ballasted Sedimentation	23	0.79
	CEPT with Lamella Plates	24	0.71
Hanford #2	Ballasted Sedimentation	68	0.94
	CEPT with Lamella Plates	70	0.77
Brandon St	Ballasted Sedimentation	24	0.41
	CEPT with Lamella Plates	25	0.33
S Michigan St	Ballasted Sedimentation	40	0.86
	CEPT with Lamella Plates	41	0.77
Consolidated King St and Kingdome	Ballasted Sedimentation	56	1.45
	CEPT with Lamella Plates	58	1.28
Consolidated Hanford #2 and Lander St	Ballasted Sedimentation	94	0.97
	CEPT with Lamella Plates	96	0.82
Consolidated Hanford #2, Lander St, and Kingdome	Ballasted Sedimentation	139	1.57
	CEPT with Lamella Plates	142	1.36

Alternative	CSO Treatment Process	Treatment Peak Flow Rate (MGD)	Equalization Basin Volume (MG)
Consolidated Hanford #2, Lander St, Kingdome, and King St	Ballasted Sedimentation	151	1.71
	CEPT with Lamella Plates	155	1.43
Consolidated S Michigan St and Brandon St	Ballasted Sedimentation	66	0.89
	CEPT with Lamella Plates	68	0.72

Kingdome WWTF

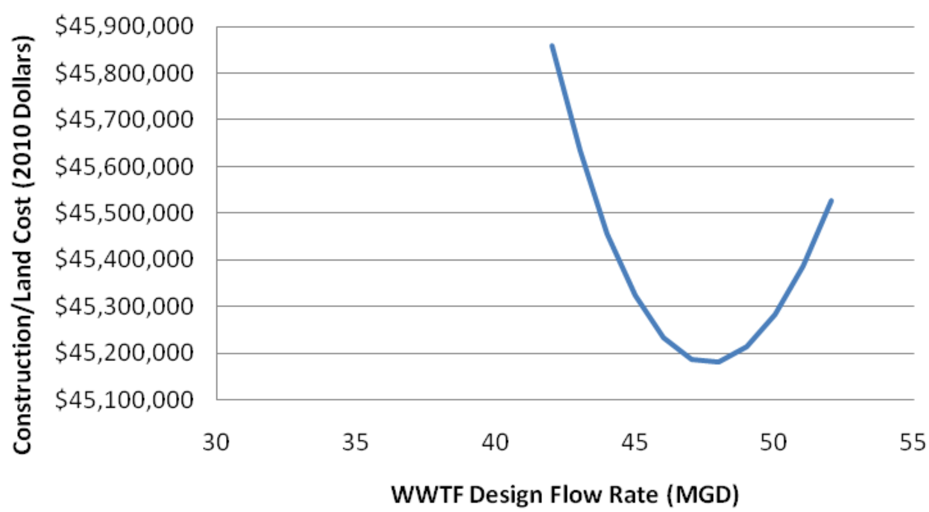

Figure F.4-6. Total Cost Curve for Kingdome WWTF (Ballasted Sedimentation)

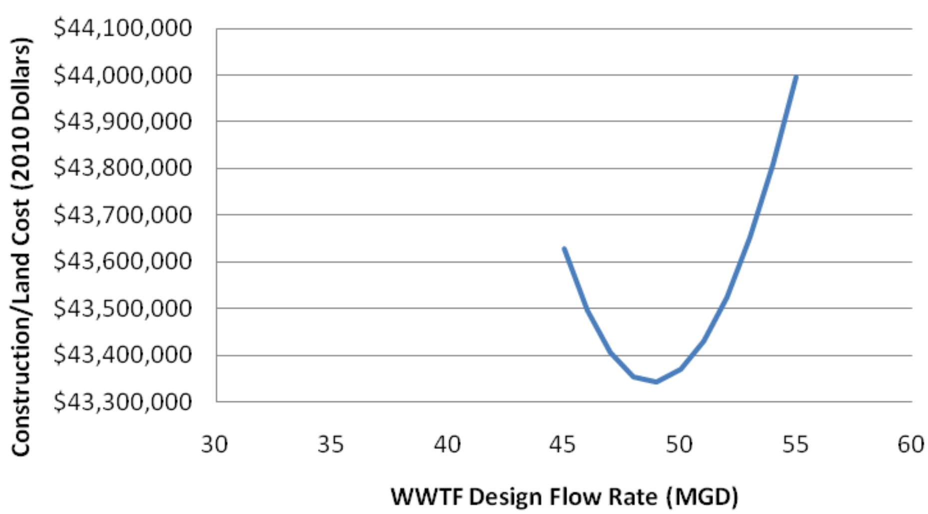

Figure F.4-7. Total Cost Curve for Kingdome WWTF (CEPT with Lamella Plates)

Lander St WWTF

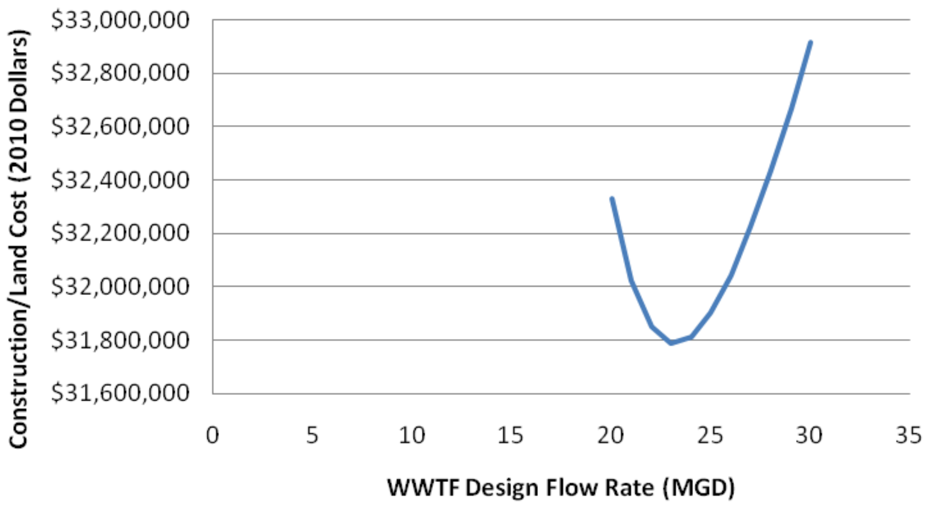

Figure F.4-8. Total Cost Curve for Lander St WWTF (Ballasted Sedimentation)

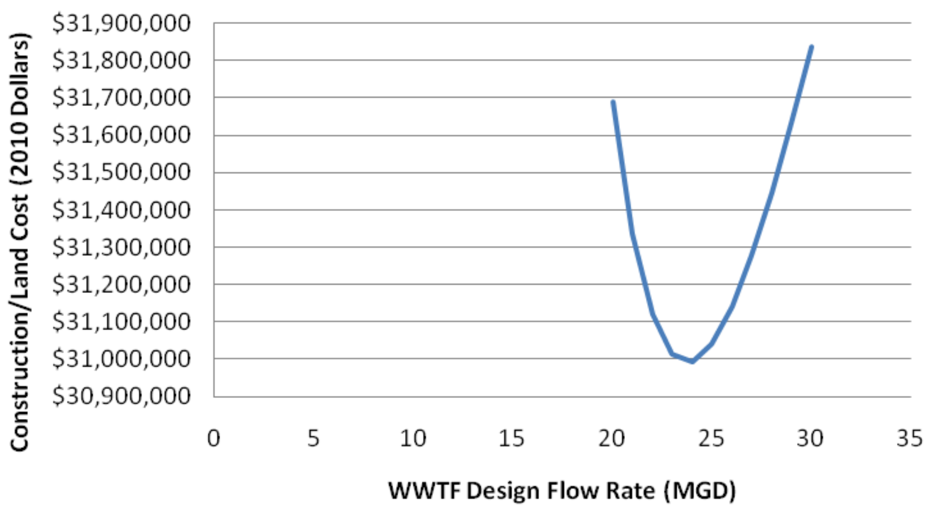

Figure F.4-9. Total Cost Curve for Lander St WWTF (CEPT with Lamella Plates)

Hanford #2 WWTF

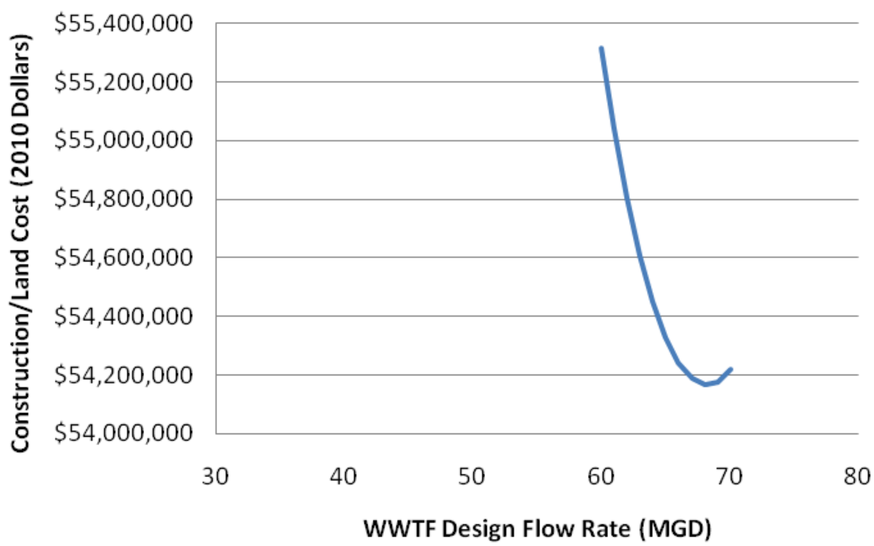

Figure F.4-10. Total Cost Curve for Hanford #2 WWTF (Ballasted Sedimentation)

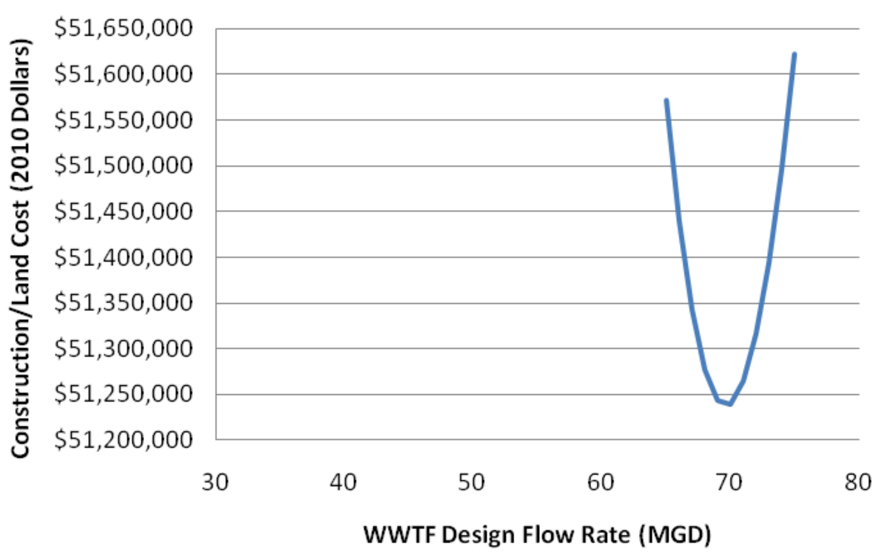

Figure F.4-11. Total Cost Curve for Hanford #2 WWTF (CEPT with Lamella Plates)

Brandon St WWTF

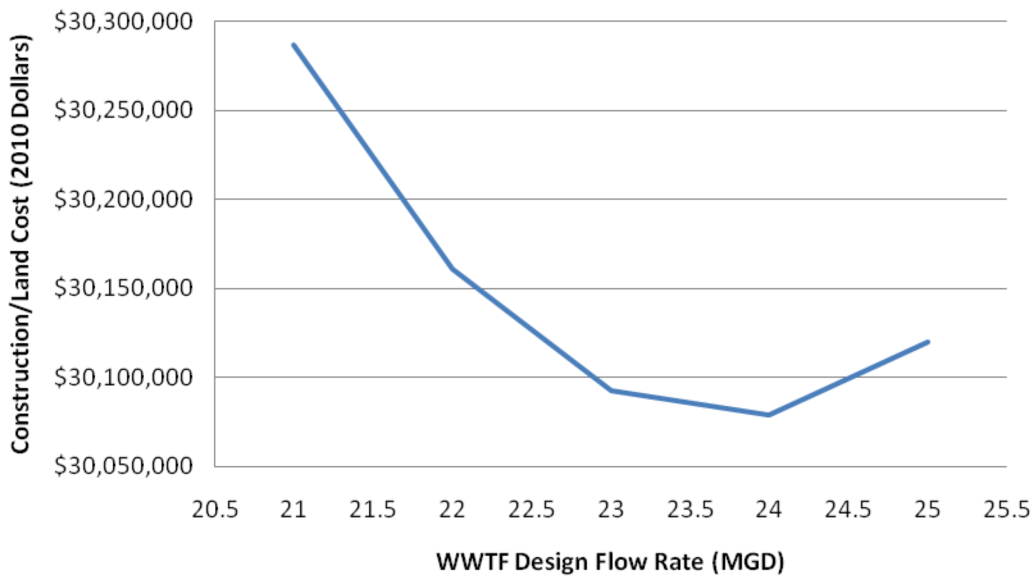

Figure F.4-12. Total Cost Curve for Brandon St WWTF (Ballasted Sedimentation)

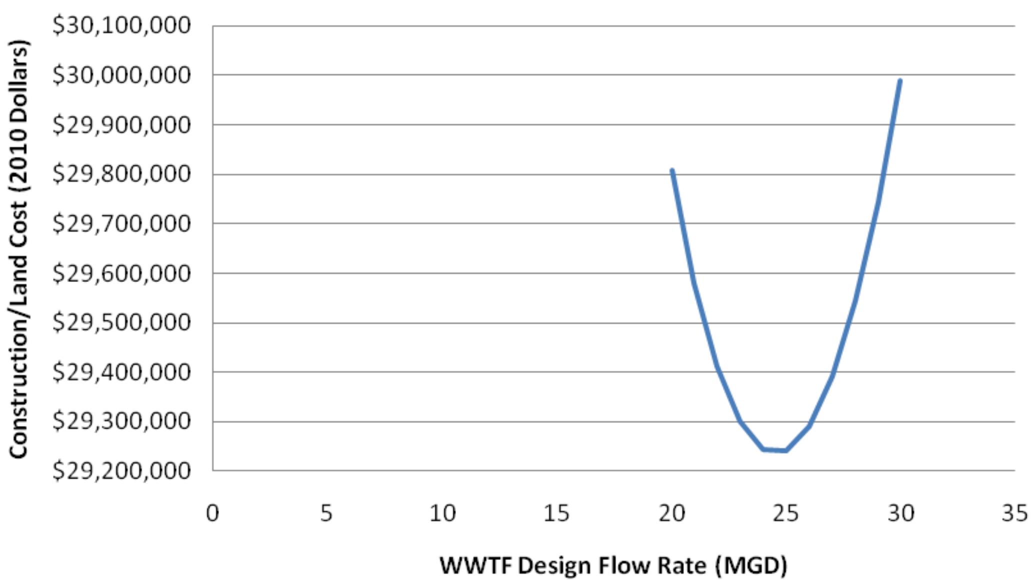

Figure F.4-13. Total Cost Curve for Brandon St WWTF (CEPT with Lamella Plates)

S Michigan St WWTF

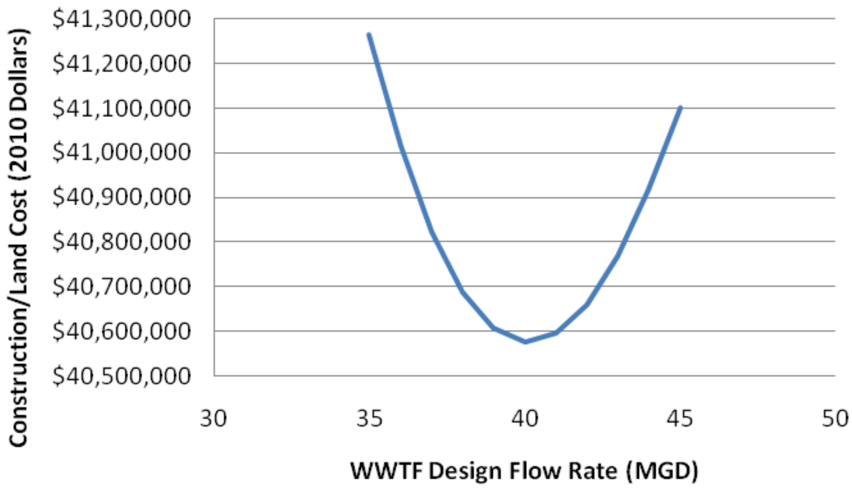

Figure F.4-14. Total Cost Curve for S Michigan St WWTF (Ballasted Sedimentation)

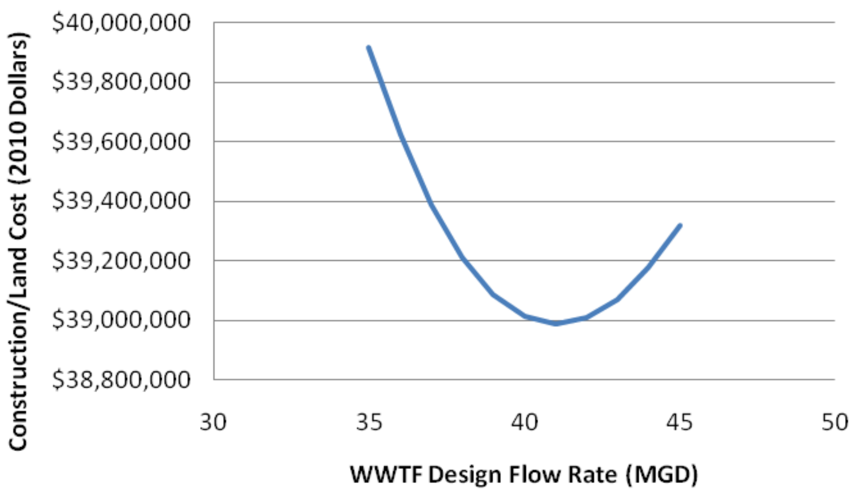

Figure F.4-15. Total Cost Curve for S Michigan St WWTF (CEPT with Lamella Plates)

Consolidated King St and Kingdome WWTF

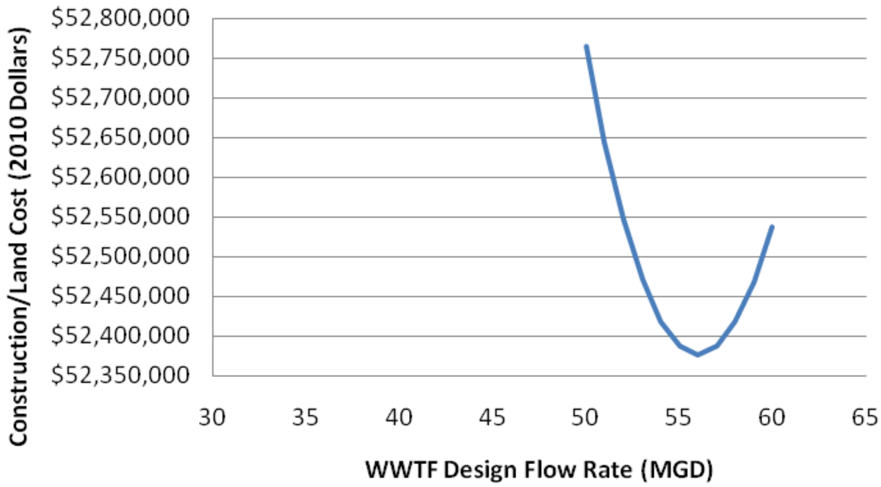

Figure F.4-16. Total Cost Curve for Consolidated King St and Kingdome WWTF (Ballasted Sedimentation)

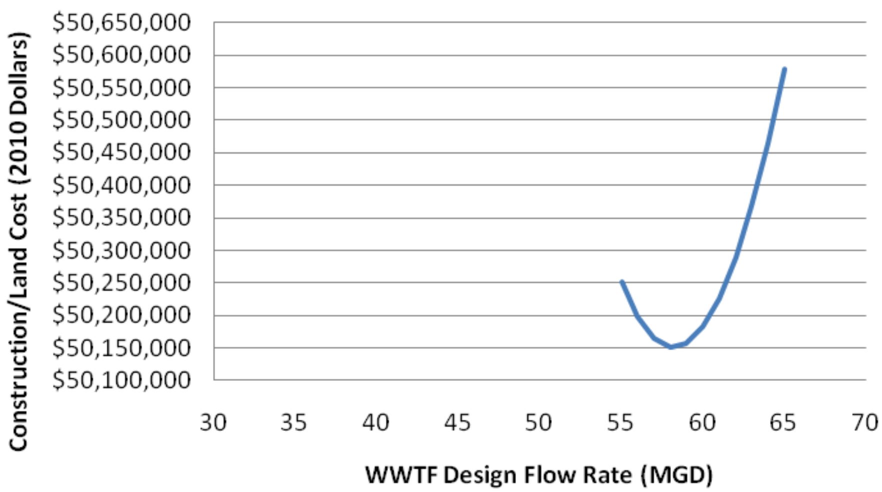

Figure F.4-17. Total Cost Curve for Consolidated King St and Kingdome WWTF (CEPT with Lamella Plates)

Consolidated Hanford #2 and Lander St WWTF

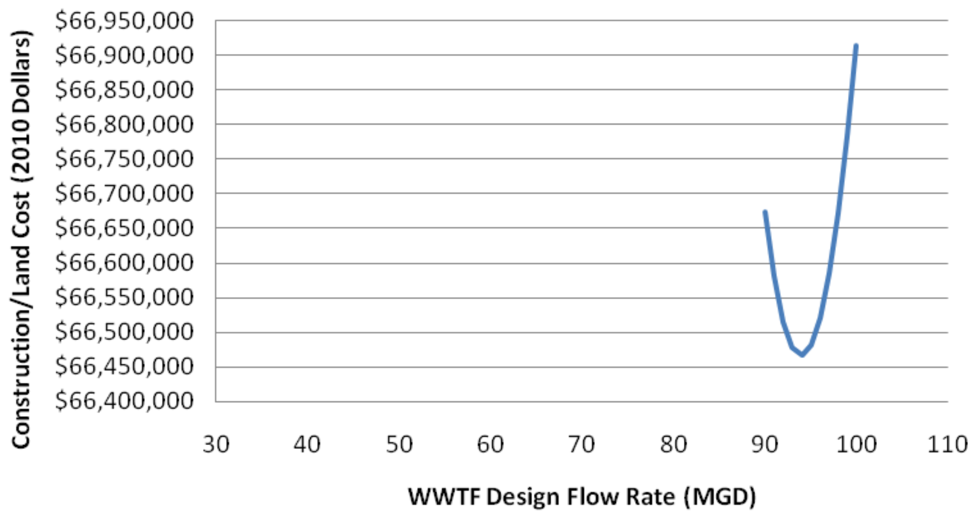

Figure F.4-18. Total Cost Curve for Consolidated Hanford #2 and Lander St WWTF (Ballasted Sedimentation)

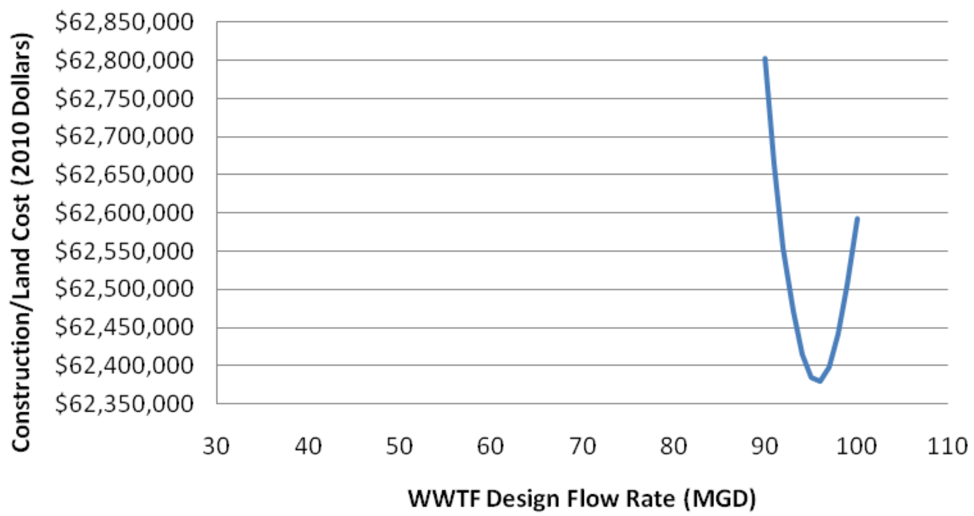

Figure F.4-19. Total Cost Curve for Consolidated Hanford #2 and Lander St WWTF (CEPT with Lamella Plates)

Consolidated Hanford #2, Lander St, and Kingdome WWTF

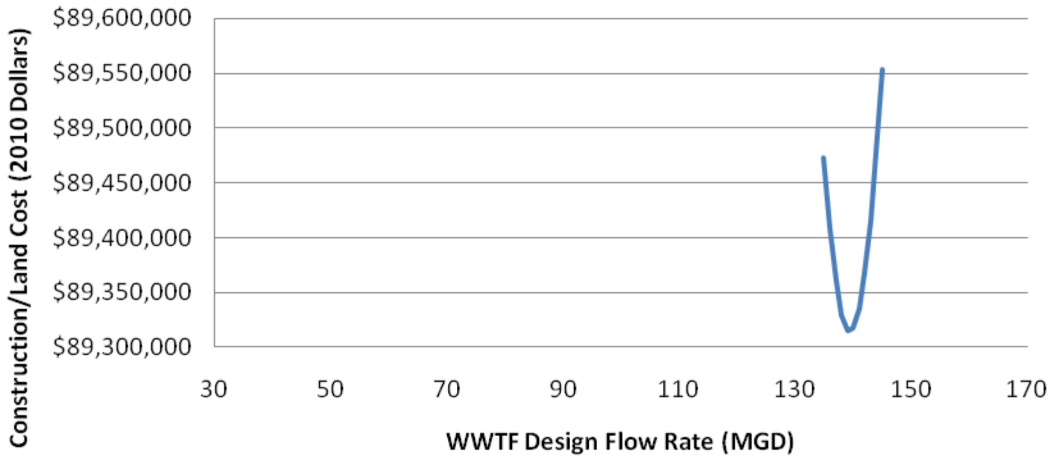

Figure F.4-20. Total Cost Curve for Consolidated Hanford #2, Lander St, and Kingdome WWTF (Ballasted Sedimentation)

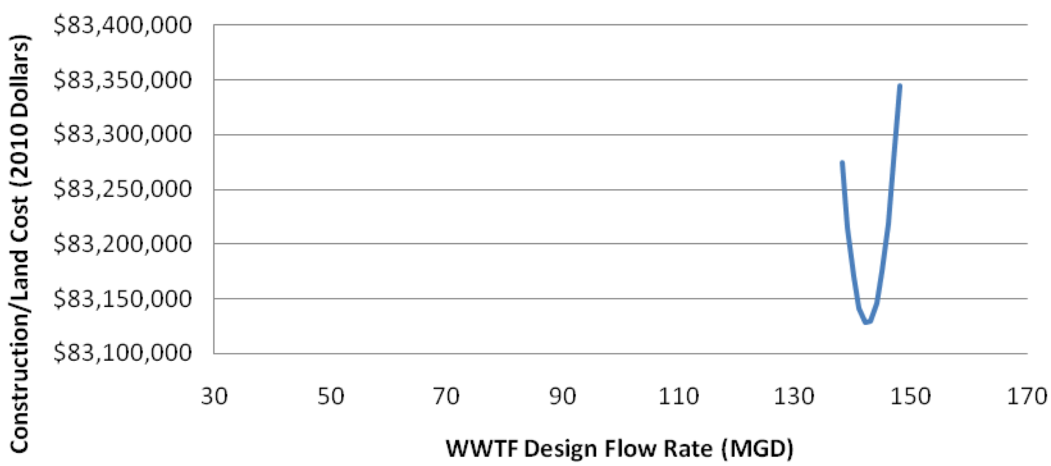

Figure F.4-21. Total Cost Curve for Consolidated Hanford #2, Lander St, and Kingdome WWTF (CEPT with Lamella Plates)

Consolidated Hanford #2, Lander, Kingdome, and King St WWTF

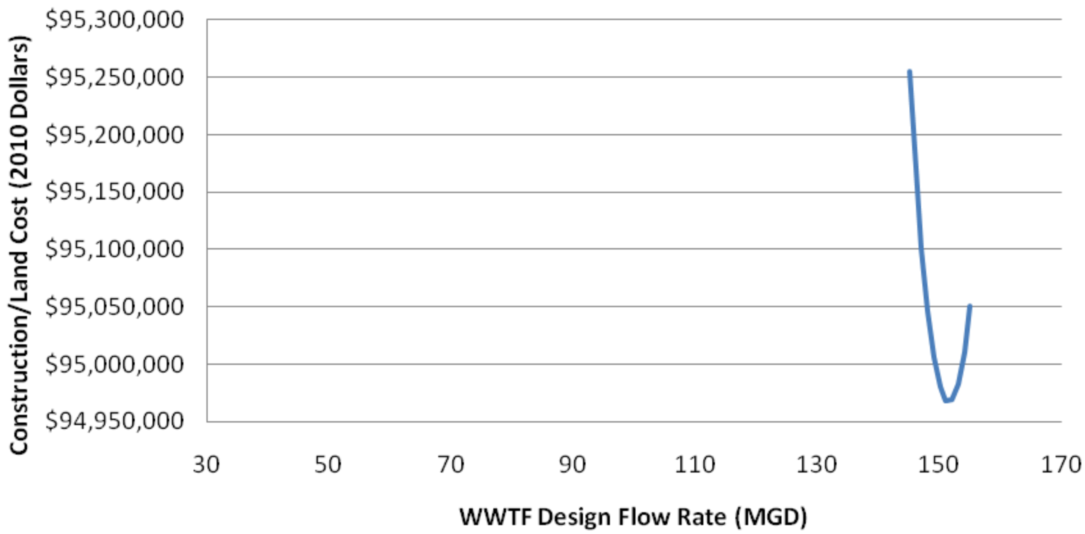

Figure F.4-22. Total Cost Curve for Consolidated Hanford #2, Lander St, Kingdome, and King St WWTF (Ballasted Sedimentation)

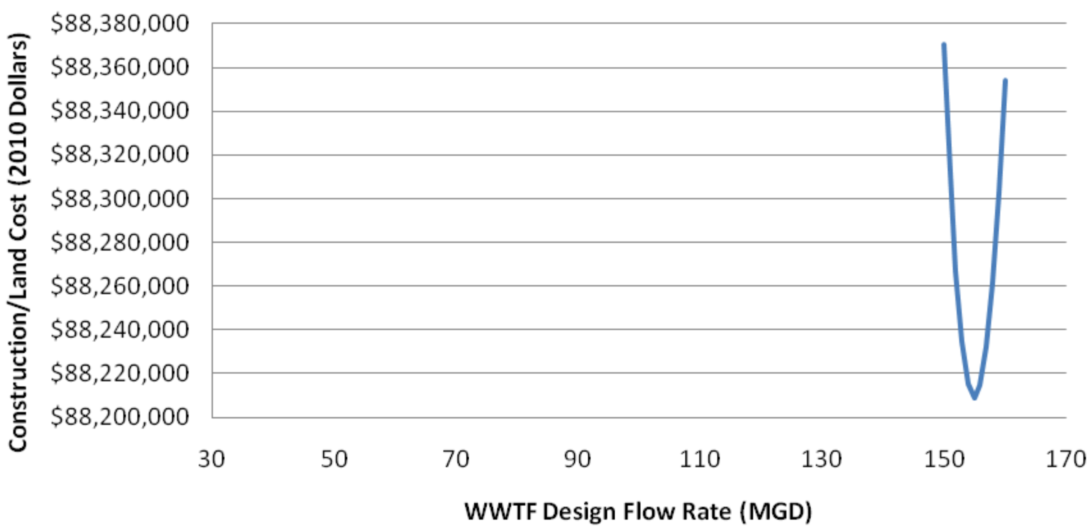

Figure F.4-23. Total Cost Curve for Consolidated Hanford #2, Lander St, Kingdome, and King St WWTF (CEPT with Lamella Plates)

Consolidated S Michigan St and Brandon St WWTF

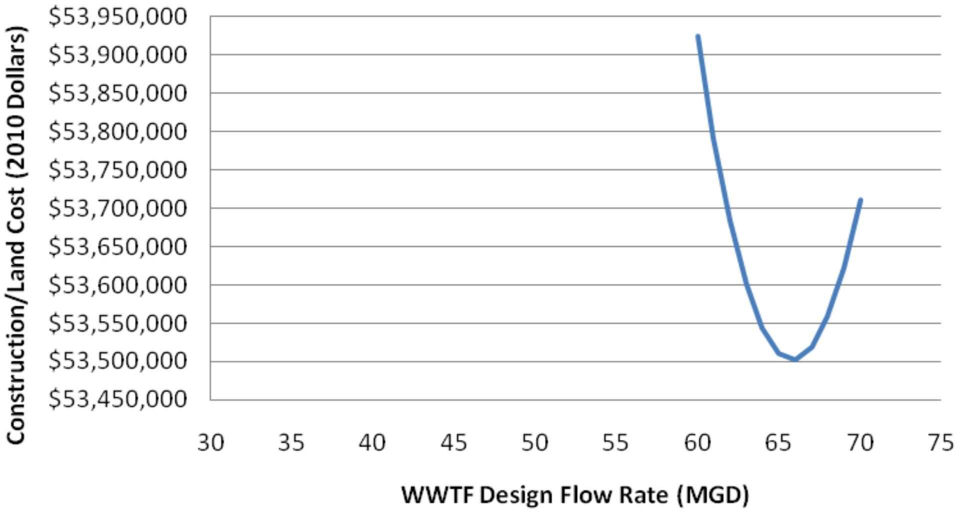

Figure F.4-24. Total Cost Curve for Consolidated S Michigan St and Brandon St WWTF (Ballasted Sedimentation)

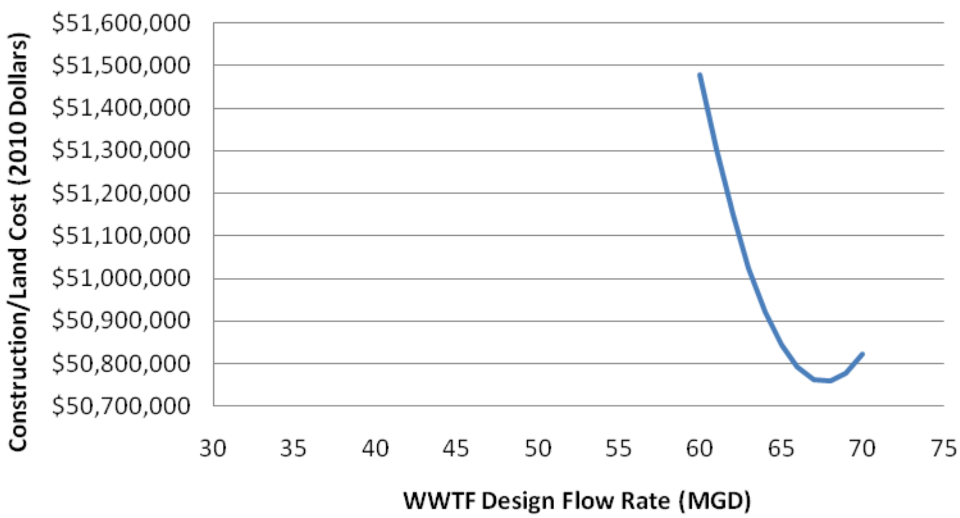

Figure F.4-25. Total Cost Curve for Consolidated S Michigan St and Brandon St WWTF (CEPT with Lamella Plates)